WHAT TO TEACH IN MY SCIENCE METHODS COURSE? ANALYSIS OF CONTENTS AND CHALLENGES DURING THE DESIGN OF ELEMENTARY, MIDDLE SCHOOL AND SECONDARY SCIENCE METHODS COURSES THROUGH A PCK LENS

by

JOSÉ MANUEL PAVEZ

(Under the direction of Julie Kittleson and David Jackson)

Abstract

Science methods courses (SMC) are a central piece of science teacher education because they integrate science content and pedagogy. Typically, science teacher educators (STEs) define the agenda for these courses. The purpose of this study is to describe the topics considered and identify the challenges facing prospective STEs (PSTEs) when designing SMC, as well as the factors influencing their pedagogical decision-making (PDM) process. I conducted a multiple case study with 10 PSTEs, who participated in an online consultation. The three cases are the design of the elementary, middle school, and secondary SMC. Participants designed a SMC syllabus, a reflection essay, among others. They participated in a think-aloud interview, oral reflections, and interviews. I conducted a thematic analysis with deductive and emergent coding. Findings show that PSTEs covered all the PCK dimensions in their syllabi across cases. Common challenges are selecting and sequencing contents. The main extra-personal factor influencing their decisions were previous SMC syllabi.

INDEX WORDS: science methods, pedagogical content knowledge, professional knowledge bases, pedagogical decision-making, elementary science methods, middle school science methods, secondary science methods, science methods course curriculum.

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A Dissertation Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

2022

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August 2022

ACKNOWLEDGEMENTS

I am very thankful to everyone that contributed in different ways to this crazy but gratifying journey of my doctoral program. I would like to thank my major professors, Dr. Julie Kittleson and Dr. David Jackson, for their guidance, patience, and for trusting in my process and scholarship. Thanks for letting me explore new areas and for believing in me. I also thank my amazing committee members, Dr. Renee Schwartz and Dr. Barbara Crawford, who also believed in me and supported me in exploring new waters. I cannot be thankful enough to all the educators that took part in my study, many of which are friends. Thanks for agreeing to join me in this process. This dissertation could not have been possible without your help. I also take this opportunity to thank my family and friends for their unconditional support through this five years process. Thanks for always being with me, despite the distance. I also need to mention my Latinx friends and colleagues who helped me to be connected with my roots and culture despite being away from home. Thanks for joining me in celebrating our culture. I could not have done this without them by my side. And thanks to all my international friends too, thanks for creating and being part of this welcoming community. Finally, I want to thank Dr. Julie Luft for her guidance and helping me grow professionally. I also want to thank ANID and NSF for funding my doctoral studies.

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CHAPTER 1

1. INTRODUCTION

Introduction and rationale

Research on science teacher educators' pedagogy is a growing field in science education (Berry & Loughran, 2012). Science teacher educators (STEs) have an essential role in preparing future science teachers nationwide to teach science effectively to diverse groups of students (Berry & Van Driel, 2013). Most of the time, STEs define the agenda of the science teaching and learning curriculum, and also, they shape how this is enacted (Loughran et al., 2012). Thus, it is crucial for researchers to pay attention to STEs' beliefs, pedagogy, and needs for engaging science teachers in meaningful learning. It has been argued that it is necessary to develop a richer understanding of a pedagogy of teacher education (Berry & Loughran, 2012). STEs have different roles in the preparation of science teachers: teaching courses on science subject matter and/or science pedagogy, school-based mentoring teachers, providing professional development in school, universities, and others (Lederman et al., 1997).

There is a big contrast between the attention of researchers to K-12 education related to what teachers need to know and do, compare with the little attention paid to what teacher educators know and need to know or the expertise they need in order to teach about teaching science (Berry & Van Driel, 2013; Witzig & Sickel, 2017). Historically, research on teacher educators (TEs) has been rare and generic; researchers have not paid much attention to how TEs can support the learning of how to teach subject matter (Berry & Van Driel, 2013). Similarly, there is a considerable number of resources to help science teachers with their practice in K-12 science teaching, but there are not enough practitioner oriented resources available for STEs to teach teachers about science teaching and learning (Witzig & Sickel, 2017).

Despite the importance given to the preparation of high-quality teachers, not much attention has been paid to organize the preparation of TEs for this task; thus, there seems to be no a single clear career to become a TE (Berry & Van Driel, 2013). A typical pathway for becoming a TE is to work as a schoolteacher for some time and then pursue a doctoral program. However, there are other pathways, like through research on a science-specific discipline (Berry & Van Driel, 2013; Mork et al., 2021). In general, there are great variations in doctoral programs in science education in terms of the opportunities STEs have to learn about science teacher pedagogy and developing PCK. Some prospective STEs may lack opportunities for teaching or co-teaching science methods courses, while others may have more structured opportunities to plan and teach these courses (Abell et al., 2009). But even when these opportunities are provided, some authors argue that they are not an optimum environment to develop PCK for teaching science teachers because they do not consider the learning needs of STEs (Abell et al., 2009). Additionally, a lack of explicit instruction on science teacher education is common in doctoral programs in science education, and one evidence of this is that science teacher education did not appear as a topic in the courses required in doctoral programs (Abell et al., 2009; Jablon, 2002). Generally, there is an overemphasis on learning to do research in doctoral programs from all disciplines, in contrast with the preparation for teaching and planning (Abell et al., 2009).

Science Methods course in science teacher education

It is common for STEs to teach elementary, middle school, or secondary science methods courses (SMC) at some point in their careers (Abell et al., 2010). In the context of science teacher education, the SMC are a central piece of this field because they are an avenue that should communicate the research on science education field with practitioners. These courses are an essential component of almost all elementary, middle, and high-school science teacher preparation programs. The SMC has been described as the "launching pad" for professional development because it set the science teacher candidate on a path of continuous professional growth as science teachers (Anderson, 1997). It is a place with the potential for promoting integration between subject matter and pedagogical perspectives, theoretical and practical dimensions, coursework, and student teaching experience (Anderson, 1997). Also this course is where program standards for science accreditation (local, state, or national) are primarily addressed (Allan, 2017). In a literature review conducted with empirical studies that focused on elementary science teacher education (Davis & Haverly, 2022), researchers found that SMCs contribute to three basic purposes in teacher preparation: supporting beliefs, attitudes, and identities, supporting knowledge, and supporting performance of future teachers.

Anderson and Mitchener (1994) recognize the methods course as one of the three major components of the professional education component of teacher education programs, besides educational foundations and field experience. They describe the SMC as follows:

> Science methods courses act as the bridge between many areas of the teacher education curriculum, as well as between education and studies in the science departments. Methods courses help prospective teachers integrate knowledge and gain experience in applying this integrated learning in actual school settings with real students or in simulated environments with peers. (p. 17)

Commonly SMCs are general methods courses, and the activities of these courses can be focused on the science subject that student teachers will teach. But depending on the program, the SMC could also be subject specific (i.e., physics methods, or methods course for biology or chemistry), although this is less common (Allan, 2017). Typically, instructors of SMC are professors from a science department or from an education department, depending on the department in which the program is located (Allan, 2017).

Research has suggested that the nature and quality of these courses are positively associated with effective teaching (Druva & Anderson, 1983; Smith, 1999), pedagogical orientations (Sahingoz & Cobern, 2020), and they have the potential to impact the practice of new teachers (Abell & Bryan, 1997; Gess-

Newsome, 2002a). For instance, Sahingoz and Cobern (2020) found that pre-service science teachers who have taken a SMC think that they should consider more factors (e.g., grade level, prior knowledge, interest areas) when selecting an instructional approach, when compared with pre-service science teachers who have not taken a SMC. Unfortunately, there has been a lack of research on the curriculum and topics that are being covered in SMC (Gilbert, 1992; Lee, 2010; Weiss, 2002; Yager, 2005), the teaching strategies used (Gilbert, 1992), and the design process of these courses. Historically, there has been a lack of attention to the expertise and professional qualifications of STEs (Lederman et al., 1997) who teach these courses. It is known that there is a great diversity in the STEs' expertise and experiences teaching science in schools or teaching teachers, and some of them have never taught science in the K-12 context (Abell et al., 2010). In recent years the situation has not changed significantly, and most of the research about SMC is conducted in the context of elementary science methods.

Sadly, there are no requirements for the inclusion of SMC in science teacher preparation by any accrediting body (Allan, 2017), although typically these programs include at least one SMC to address the standards that require student teachers to have the science specific pedagogical knowledge to teach science (Allan, 2017). In addition to this, there has been a historical lack of consensus goals for the SMC (Smith & Gess-Newsome, 2004), and we observe the same scenario until these days. Typically, these courses are designed and taught autonomously by STEs (Berry & Van Driel, 2013; Smith & Gess-Newsome, 2004). In addition to selecting contents based on research literature they believe is important for prospective teachers to learn, STEs generally select topics they feel comfortable with (Lee, 2010). This may lead to big differences between different programs or even within one particular program (Berry & Van Driel, 2013). And this consequently will lead to big differences in what student science teachers take away from these courses and what is important to know and do in order to effectively teach science. Additionally, it is unclear if STEs are considering national science education standards in the design of SMC (Smith & Gess-Newsome, 2004).

In this context, I am interested in research about the design process of SMC by prospective STEs in different stages of their doctoral programs.

Conceptual Framework

Pedagogical Content Knowledge in Science Teacher Education

Researchers in science education recognize pedagogical content knowledge (PCK) as an essential and unifying topic for science teacher education field (Loughran et al., 2012; van Driel et al., 2014). This idea was originally proposed by Shulman (1986), who initially distinguished three dimensions or categories of knowledge in the mind of teachers: subject matter content knowledge, pedagogical content knowledge, and curricular knowledge. Here he describes the concept of PCK as follows: "[PCK] goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching... [PCK] embodies the aspects of content most germane to its teachability" (p. 9). Here, Shulman included aspects like the forms of representation, analogies and illustrations of topics, and students' preconceptions. Later on, several researchers have developed, elaborated, revised, refined this model.

After Shulman, two influential models for teacher knowledge were the "Knowledge bases for teaching" by Grossman (1990), and the Magnusson et al. (1999) PCK model. Knowledge bases for teaching (Grossman, 1990) model includes four dimensions: knowledge of context, subject matter knowledge, pedagogical knowledge, and pedagogical content knowledge. The last one includes five sub-dimensions that are also included in Magnusson et al. (1999) model specifically for science: orientation to teaching science, knowledge of science curricula, knowledge of assessment of scientific literacy, knowledge of student's understanding of science, and knowledge of instructional strategies.

These models have served as a framework for several other models, such as the pentagon model proposed by Park and Oliver (2008a). This model includes the same five sub-dimensions found in Magnusson et al. (1999) model. An important difference is an emphasis on the interrelatedness and integration among the components; thus, the development of one component will influence the development of others. Another difference is the addition of 'reflection' in the integration of the different components. Also, PCK is placed in the center of the pentagon to indicate it can be developed from any of the five components. Park and Oliver (2008b) synthesized some definitions of PCK proposed by different researchers as follows:

> It is transformation of subject matter knowledge for the purpose of teaching that is at the heart of the definition of PCK. In other words,

> it is commonly stated that PCK is used to adapt subject matter knowledge for pedagogical purposes through a process (p. 264)

The most recent iteration of this framework has been called the Refined Consensus Model (RCM) of PCK (Carlson & Daehler, 2019). Something new in this model is that the authors recognize three types of PCK:

- *collective PCK* (cPCK) refers to the "specialized professional knowledge held by multiple educators in a field" (p. 83).

- *personal PCK* (pPCK) refers to the "personalized professional knowledge held by an individual teacher in science" (p. 83).

- *enacted PCK* (ePCK) refers to the "subset of knowledge that a teacher draws on to engage in pedagogical reasoning during the planning of, teaching of, and reflecting on a lesson" (p. 83).

It has been argued that science teachers should develop the cPCK in their teacher preparation programs, and that school practicum is a good place to develop ePCK and pPCK (Sorge et al., 2019). The model also recognizes the *professional knowledge bases* as a foundation for teacher's PCK, which includes pedagogical knowledge, knowledge of students, curricular knowledge, assessment knowledge, and content knowledge. Finally, the model also considers the *learning context*, like policies or community values, as another factor influencing teaching and learning.

Since its creation, the different versions of PCK models have been applied to diverse aspects in the science education field and in different contexts. For instance, Abell et al. (2009) state that there is a parallel between PCK for science teachers and PCK for science teacher educators. Based on Grossman (1990) and Magnusson et al. (1999), Abell et al. (2009) proposed a PCK model for teaching science teachers (**Figure *1***). The different dimensions in this model are:

- Subject matter knowledge, which includes science content and knowledge for teaching science.

- Knowledge of curriculum for teaching methods courses.

- Knowledge of assessments in methods courses.

- Knowledge of instructional strategies for teaching methods courses.

- Knowledge of teachers' understanding of science and science teaching.

The authors proposed this model for supporting the learning of novice STEs about teaching science teachers. They argue that the different dimensions of the model should be explicitly addressed during the doctoral programs.

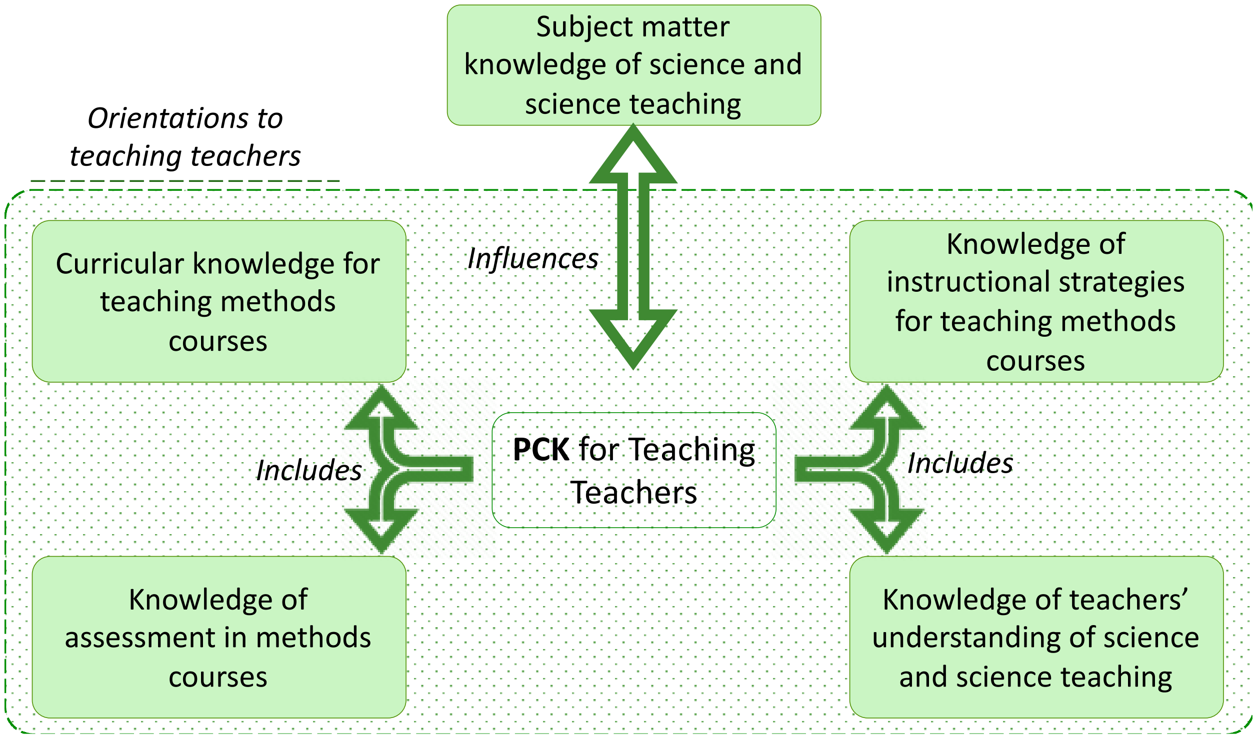

Figure 1. PCK model for teaching science teachers proposed by Abell et al. (2009) who adapted PCK models from Grossman (1990) and Magnusson et al. (1999).

At a more specific level, it has also been argued that PCK has a crucial role in SMC. Abell et al. (2010) argue that STEs draw on their own PCK for designing and implementing their SMC. Abell et al. (2010) also state that "a key goal of your methods course, explicitly stated or implicit, is to help your methods students develop sufficient PCK for teaching science, to enable them to commence teaching science—what might be called a 'starter pack.'" (p. 12). For these authors, the main aim of a method course is "to produce graduates who are ready to commence teaching science. That is, they have a "starter pack" of PCK for science teaching." (p. 81).

In an analysis of different SMC from different continents, Sickel and Witzig (2017) found a close alignment between the topics taught in those courses and the components of PCK models. Because of this and given the importance of PCK for science teacher education, and for the design of science methods courses, it was be used as an analytic framework. It served as a tool for interpretation and organization of the findings of this research. A combination of the different dimensions of PCK models presented here was considered to conduct a qualitative deductive analysis of the data. Particularly the PCK dimensions of the pentagon model and the professional dimensions of the RCM. The purpose of this study is not to measure participants' PCK for teaching science teachers; rather, it is studying what aspects of PCK are covered in their syllabus to understand which dimensions of this model are more prominent in their syllabus and which of them are lacking attention. These models were only used as an organizational framework for coding data. Initially, only the pentagon PCK model was considered, but as I was conducting the preliminary analyses, I noticed that many of the contents included by participants covered some of the professional knowledge bases identified in the RCM model, so I decided to include these dimensions to organize these other generic contents that are not included in the pentagon PCK model.

Specifically, the PCK dimensions from the pentagon model (Park & Oliver, 2008a) were considered in conjunction with the Professional Knowledge Bases of the RCM of PCK (the outer ring) (Carlson & Daehler, 2019). It was not possible to include in this study any of the three types of PCK from the RCM for different reasons. For instance, Enacted PCK (ePCK) was not considered given that it is hard to make inferences of their ePCK based on a syllabus without actually being in the classroom since "ePCK is so specific to a particular science teaching episode" (Carlson & Daehler, 2019, p. 85) and it is “utilized by an individual teacher in a particular setting, with a particular student or group of students, with a goal for those students to learn a particular concept” (Carlson & Daehler, 2019, p. 85). Additionally, that is not a purpose of this study. Similarly, personal PCK (pPCK) wasn’t consider because the goal of the study was not to measure the “reservoir of knowledge and skills that the teacher can draw upon during the practice of teaching” (Carlson & Daehler, 2019, p. 85). Instead, the purpose of the study was to characterize the dimensions/topics considered by PSTEs in their SMC to understand if they were providing future science teachers with adequate knowledge to develop sufficient PCK for teaching science. Finally, collective PCK (cPCK) was not considered either because it has been described as the knowledge articulated, shared and used by any group of educators and/or researchers and “recognizes that knowledge about science teaching is also developed within school districts, school sites, departments, grade-level teacher teams, and professional learning communities (i.e., local collective PCK) (Carlson & Daehler, 2019, p. 85). In this study, participants were from 3 different institutions, and they are in different cohorts in their doctoral programs, so most of them haven’t developed this knowledge collectively. Additionally, since the RCM does not provide sub-dimensions for any of the three types of PCK, the sub-dimensions of the pentagon model (Park & Oliver, 2008a) were used here to further delineate PCK. These models are useful for thinking about the major topics addressed in the designed SMC. A representation of these models is presented in **Figure *2***. Additionally, Abell et al. (2009) PCK model for teaching science teachers was used for interpretation purposes.

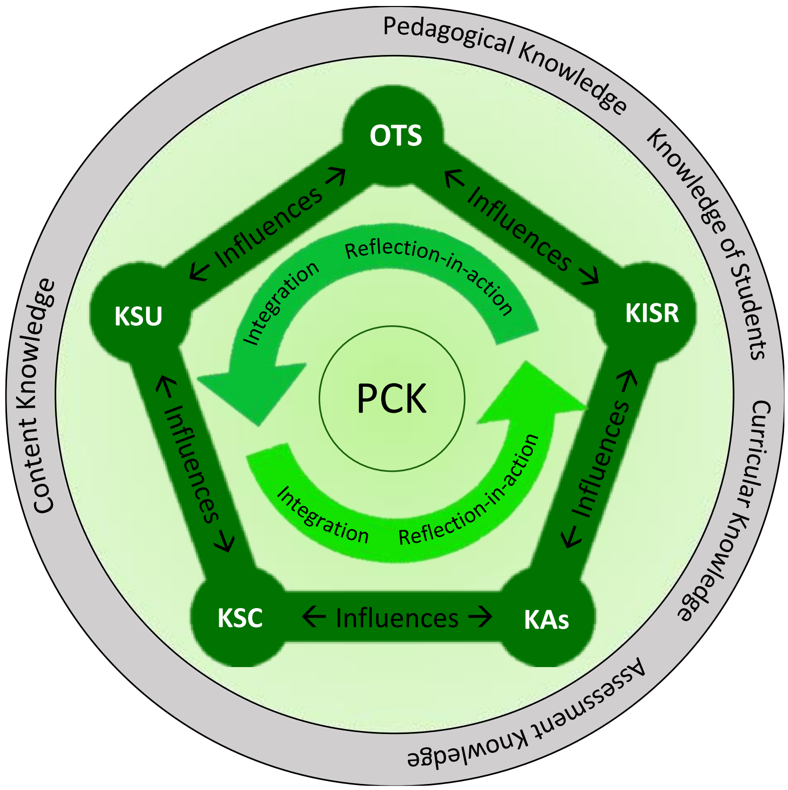

Figure 2. Dimensions of PCK pentagon model and professional knowledge bases from RCM considered in the study.
(*OTS: Orientation to teaching science; KISR: Knowledge of instructional strategies and representations for teaching science; KAs: Knowledge of assessment of science learning; KSC: Knowledge of science curriculum; KSU: Knowledge of students' understanding in science*.)

Pedagogical Decision-making in teacher education

Science teachers, and teachers in general, have to make hundreds of pedagogical decisions every day (Clough et al., 2009). These decisions can be related to the science content to be taught, the tasks and activities to engage students in the learning process, the required materials for those activities, teaching models, strategies, teacher behaviors, among others (Clough et al., 2009). Some of these decisions are made before a particular teaching event, and some others are made during and after a teaching event.

Similarly, STEs also have to make multiple pedagogical decisions when it comes to educating prospective science teachers. Depending on what aspects of science teacher preparation an STE is working, they may need to make decisions about the courses and experiences that are relevant to student teachers, for instance. Frequently, they also need to make more specific decisions about the contents of the courses they teach, the readings and activities for these courses, the teaching approaches, the assessment, behaviors in class, among multiple others.

A difference between science teachers' pedagogical decisions and STEs' pedagogical decisions is that science teachers typically have local or national curricular documents to help them with the selection of topics and strategies for lesson planning. Most of the time, STEs do not have curricular documents to help them with the design of specific courses in science teacher preparation, including here the SMC. Depending on the country, STEs may have access to science teacher preparation standards (i.e., 2020 NSTA/ASTE Standards for Science Teacher Preparation in the USA), or exit requirement examinations (i.e., Praxis Series Test, edTPA, formerly teacher performance assessment, in the USA, depending on the state). These documents provide guidelines to plan and organize a teacher preparation program, but they could be less useful for designing particular courses within that program.

Pedagogical decision-making (PDM) was recognized as a key element to understand and improve teaching in the early 70s (Borko et al., 2008). Three scholars - Bishop, Shulman, and Shavelson - independently proposed this cognitive framework for teaching decision-making in a particular situation (Borko et al., 2008).

PDM has been defined as "the fundamental link between complex, real-time teaching situations and practical actions in classrooms" (Borko et al., 2008, p. 39), based on the work of three influential scholars in this field (Bishop, Shulman, and Shavelson). This definition of PDM emphasizes decisions made in real-time during a teaching situation. However, in addition to these decisions, multiple other decisions need to be made before the teaching event. In this regard, some authors recognize two types of PDM. One type of decisions are *pre-lesson decisions* (Bishop & Whitfield, 1972) or *long-term decision-making* (Henze & Barendsen, 2019), which involves the pedagogical decisions made during the planning phase of a teaching event or course design. They can include decisions about objectives, content, method or materials. These types of decisions involve personal PCK (pPCK), which is described as the "personalized professional knowledge held by an individual teacher" (Carlson & Daehler, 2019, p. 82). The second type is *short-term decision-making* (Henze & Barendsen, 2019) or *within-lesson decisions* (Bishop & Whitfield, 1972), also known as *decision-making-on-the-spot* (Borko et al., 2008), and it involves the pedagogical decisions made during the enactment of the planned teaching event/course, and can include decisions related to the implementation or modification of pre-lesson decisions, language level, the number or types of examples, motivating and reacting to individual student's needs, among many others. These types of decision affect enacted PCK (ePCK), which is described as "the unique subset of knowledge that a teacher draws on to engage in pedagogical reasoning during the planning of, teaching of, and reflecting on a lesson" (Carlson & Daehler, 2019, p. 82). The present study focuses on the first type of PDM, the *long-term decision-making* or *pre-lesson decisions,* since it centers on the planning phase of an SMC and not on its implementation.

Clough et al. (2009) proposed a framework for PDM to visualize and conceptualize the many pedagogical decisions that teachers need to make and their interactions. The purpose of this framework is to help teachers to make sense of the complex decisions they make, many times unknowingly, and make the whole PDM process more explicit. In this model, teachers' decisions are organized into three groups: (1) decisions regarding science content, tasks, activities, and materials, (2) teaching models and strategies, and (3) teacher behaviors and interaction patterns. According to this model, these decisions should be made considering the desired goals for students and how students learn. The authors propose multiple uses for this framework, such as guiding self-reflection on and in action, emphasizing the crucial role of the teacher, supervision, planning lessons, and structuring SMC and programs. For the latter example, the authors propose using their decision-making framework as a lens to process activities, critique lesson plans, analyze videotaped lessons, analyze their teaching practices, as well as for deciding about the contents, tasks, materials, teaching models, and strategies, among others.

Henze and Barendsen (2019) also recognize two overarching types of factors influencing the decision-making process of teachers. These are personal factors and extra-personal factors. *Personal factors* could include teachers' internal factors such as interest and value beliefs, self-concept, self-efficacy, self-esteem, and control beliefs, among others. *Extra personal factors* could include external factors associated with a particular teaching situation, like grade level of students, the curricular context, the structure of the course or program, the culture/politics of the institution, among others. These types of factors were used for analysis purposes as overarching categories to organize the factors identified in this study. **Figure *3*** presents as schema for PDM based on these authors.

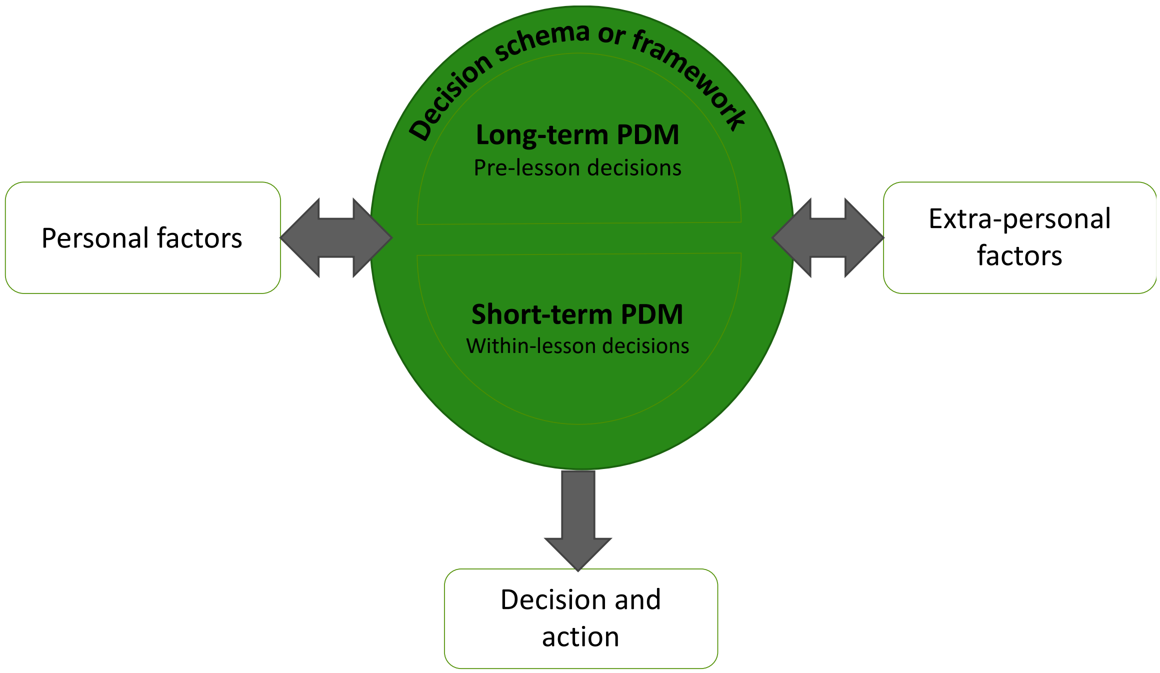

Figure 3. Pedagogical decision-making framework (*PDM: Pedagogical decision-making*) [Based on (Bishop & Whitfield, 1972; Borko et al., 2008; Henze & Barendsen, 2019)]

Significance of the study

Because of the crucial role of science teacher educators and the science methods courses in the education of future science teachers, and because of the lack of attention in the literature to STEs' pedagogy and the topics and goals of SMC, it is relevant to understand how STEs design these courses. For these reasons, this study aims to improve our understanding of the topics/dimensions considered by PSTEs when designing SMC, the challenges they face during this process, and factors that may be influencing their decisions.

Purposes and Research Questions

Purposes

- To characterize the dimensions/topics considered by prospective science teacher educators when designing a science method course
- Identify challenges that prospective science teacher educators encounter when designing a science method course
- Identify potential factors influencing prospective science teacher educators' pedagogical decisions when designing a science method course

Research questions

RQ1. What are the dimensions/topics considered by prospective science teacher educators when designing a science method course?

RQ2. What are the challenges that prospective science teacher educators encounter when designing a science method course?

RQ3. What are potential factors influencing prospective science teacher educators' pedagogical decisions when designing a science method course?

CHAPTER 2

2. REVIEW OF THE LITERATURE

Overview of the curriculum of science teacher preparation programs around the world

There is great variation in terms of the curriculum of teacher preparation programs in different countries and even within the same country. Each institution decides on the curriculum and methods to prepare prospective teachers and many times they do not know how other teacher preparation institutions are educating in-service teachers (Smith & Gess-Newsome, 2004). These programs have differences in the emphasis on content knowledge versus pedagogical knowledge versus science pedagogy, for instance. Participants in this study completed their education degrees and got their teacher certifications in different countries. Consequently, a review of the different perspectives on teacher preparation in different countries could contribute to having a better idea of the diverse backgrounds of this group of participants.

There are two common models to organize the coursework in science teacher preparation programs: the concurrent and consecutive or sequential models. In the concurrent model, science content courses and pedagogy courses are thought simultaneously throughout the teacher preparation program. In the consecutive or sequential model, graduates from science programs interested in teaching science will take pedagogy courses after they have completed their degrees (Olson et al., 2015). Some countries offer both models, like Canada (Olson et al., 2015; Pedersen et al., 2017; Tippett & Milford, 2017), Israel (Orion, 2017; Pedersen et al., 2017), South Africa (Taylor et al., 2019), and many other countries. In most Latin American countries it is most common to see the concurrent training model (Cofré et al., 2015; Furman & Luzuriaga, 2017), as well as in France (Evagorou et al., 2015; Fuchs-Gallezot & Coquidé, 2017), Germany (Neumann et al., 2017) and Japan (Isozaki & Ochi, 2017; OECD, 2019; Ramírez & Mekochi, 2015).

There is a global trend in the preparation of science and mathematics teachers in recognizing the importance of developing student teachers' PCK (Aydin et al., 2015; Pedersen et al., 2017). PCK has also been recognized as an organizing framework for the science pedagogy courses to help student teachers to develop their PCK for teaching science (Abell et al., 2010; Sickel & Witzig, 2017).

Considering the multiple dimensions recognized in the PCK models, it is easy to notice the variations on the emphasis in science teacher preparation programs around the globe, and even within the same country. In terms of coursework, science teacher preparation programs typically cover three main areas with different emphasis: general pedagogy, science content, and science pedagogy (Pedersen et al., 2017).

In the case of the United States, science teacher preparation programs require a number of credit hours ranging between 120 and 128 hours (Allan, 2017). Typically, teacher preparation programs have on average 51 hours of general studies (liberal arts) coursework, 38 hours in their content areas, 28 hours of professional teacher education courses, and 14 clinical hours (Wang et al., 2003). The requirement of hours in a classroom can vary from 15 to 30 hours (Allan, 2017). There is a great variation in these numbers across the country, and even within the same state (Johnson et al., 2012). Most teacher preparation programs in the USA offer courses in general pedagogy, such as educational assessment, adolescent psychology, classroom management, and instruction (Allan, 2017). Also, it is common for science teacher preparation programs to offer at least one SMC, which could be a subject specific SMC (i.e., physics methods, or methods course for biology or chemistry), but most commonly it is a general SMC, depending on the size of the program (Allan, 2017).

In the case of Canada, the length of the programs can vary according to the model. For instance, it could be eight to 20 months in the case of teacher preparation programs using a consecutive model with entrance after completing a university degree; or five years in the case of teacher preparation programs using the concurrent model with entrance directly after high-school, where teachers students could receive a combined degree (i.e., B.Ed./ B.S.) (Olson et al., 2015). In Canada, general education or foundation courses could represent around 29% of teacher preparation curricula (Olson et al., 2015; Pedersen et al., 2017; Tippett & Milford, 2017). Examples of foundation courses required for all education students, regardless of their subject area or level are history, philosophy, ethics, and sociology of education. Some examples of general pedagogy courses are learning theory, assessment, special education or exceptionalities, and classroom management, which are core requirements (Tippett & Milford, 2017). Content knowledge courses could represent up to 60% of the curricula (Olson et al., 2015; Pedersen et al., 2017; Tippett & Milford, 2017). In the consecutive model, this content knowledge is acquired during their undergraduate studies. In addition to the required undergraduate coursework (e.g., biology, chemistry, earth science, and physics), the expectations set by curricular documents (i.e. Framework for Science Outcomes K-12) (CMEC, 1997) are also considered to ensure consistency in the content knowledge included in admission requirements for science teacher education programs (Tippett & Milford, 2017). Science pedagogy courses could represent around 11% of the curricula of teacher preparation programs (Olson et al., 2015; Pedersen et al., 2017; Tippett & Milford, 2017) with the goal of emphasizing PCK in specific content areas. Similar to the USA, in Canada the SMC can also be general SMC or discipline specific SMC (e.g., intermediate science methods or methods in secondary physics) (Tippett & Milford, 2017). The number of credit hours for these courses varies from only nine credit hours up to 36 credit hours (three courses) (Tippett & Milford, 2017).

Content knowledge in science teacher education

Science content courses typically represent a significant portion of the curriculum of science teacher programs. For instance, in England, science content courses can represent up to 75% of the coursework (Pedersen et al., 2017). This could be related to the fact that typically the students need to complete the requirements for a bachelor's degree in science first, and after this, they complete one year of coursework focused on science education to obtain their certification for teaching. Similarly, in countries like the Czech Republic (Valenčič & Vogrinc, 2011), science content courses represent between 60% and 70% of the coursework, and in Slovenia this proportion can go up to 80% (Štemberger, 2020; Valenčič & Vogrinc, 2011).

This high proportion of science content courses in the curriculum of science teacher preparation programs contrasts with the findings of studies showing that developing content knowledge (CK) or curricular knowledge (CuK) alone is not enough for effective teaching, and that it is necessary to develop teachers' PCK as well (Förtsch et al., 2016; Mahler et al., 2017; Zeidler, 2002). For instance, Mahler et al. (2017) studied the relationship between different types of teachers' professional knowledge (CK, CuK, PCK) and their students' performance. The authors analyzed data from 48 biology teachers and compared their professional knowledge with their students' achievements (N = 1036). The findings showed a positive and significant relationship between teachers' PCK and students' performance but not between teachers' CuK or SMK and their students' performance. These authors recommend strengthening PCK in pre-service and in-service science teacher education by offering PCK-related courses for instance, or courses were CK and PCK are integrated. In these courses, student teachers could simultaneously learn specific science concepts, how to integrate these contents in a lesson plan, what are typical students' conceptions or difficulties to learn this topic, and how to teach it. In other words, the PCK related to a specific science topic. Science methods courses are a potential course where this integration could take place.

Contrary to this trend of including a high proportion of science content courses in teacher preparation, in some countries like Japan (OECD, 2019; Pedersen et al., 2017; Ramírez & Mekochi, 2015), Turkey (Aykac & Sahin, 2018; Pedersen et al., 2017), and France (Evagorou et al., 2015; Pedersen et al., 2017), science content courses represent slightly over 30% of the teacher preparation curricula.

Pedagogical knowledge in science teacher education

Regarding the *general pedagogy* courses, they consistently represent a smaller proportion of teacher preparation in different countries compared to the science content courses. General pedagogy can represent as little as 5% in places like England (Pedersen et al., 2017), which can be explained by the high proportion of science content courses in these programs. Similarly, Slovenia (Štemberger, 2020; Valenčič & Vogrinc, 2011), Portugal (Marques & Costa, 2017), France (Evagorou et al., 2015; Fuchs-Gallezot & Coquidé, 2017) and Turkey (Aykac & Sahin, 2018; Türkmen, 2017) are some of the countries where general pedagogy courses represent 10% or less of the curriculum of science teacher preparation programs. In contrast, in countries like Japan (Isozaki & Ochi, 2017; OECD, 2019; Ramírez & Mekochi, 2015) and Macau (Liu & Liu, 2017), general pedagogy courses represent around 50% of the coursework. On average, general pedagogy courses range between 20% and 30% of the curricula of science teacher preparation programs.

The different PCK models recognize the relevance of general pedagogy as an essential knowledge to develop in science teachers and as a foundation for teacher's PCK. The refined consensus model (Carlson & Daehler, 2019) considers pedagogical knowledge (PK) as part of the professional knowledge bases (the outer ring), and it includes aspects like understanding how to set up a classroom, or how to implement collaborative learning strategies, or addressing students' special needs. Carlson and Daehler (2019) argue that this generic pedagogical knowledge is mostly developed in science teacher preparation programs, and later it can be strengthened through teaching experiences. This is why it is crucial to provide teachers with a solid base on general pedagogy during their initial teacher preparation, so they can build up on these learnings later in their teaching experiences.

Science Pedagogy (i.e., PCK) in science teacher education

Of the three main areas covered in science teacher preparation programs, *science pedagogy* represents the smallest proportion of the coursework. In most countries, it represents less than 15%, except for France (Evagorou et al., 2015; Fuchs-Gallezot & Coquidé, 2017) and Turkey (Aykac & Sahin, 2018; Türkmen, 2017), where these courses represent, on average, 39% of the curriculum of their teacher preparation programs. It is worth mentioning that in these two countries, the proportion of general pedagogy courses is low (≤ 10%), which can explain the major ratio of science pedagogy courses, also known as science methods courses, like in the USA context, or science didactic courses, like in Chile, Germany and Portugal. In contrast, there are countries where science pedagogy courses typically represent as low as 5% of the curriculum, like in Argentina (Cofré et al., 2015; Furman & Luzuriaga, 2017) and Slovenia (Štemberger, 2020; Valenčič & Vogrinc, 2011). The latter requires an average of 80% of science content courses, which can explain the smaller ratio of science pedagogy courses.

SMCs play a crucial role in science teacher preparation because they can offer a space to integrate science content knowledge and pedagogical content knowledge, as well as theoretical and practical dimensions of teacher preparation

(Anderson, 1997), integrations that have been suggested in the literature to support teachers in developing their PCK and improve science teacher preparation in general (Mahler et al., 2017). Despite researchers have reported findings about the positive impact of SMC on teachers' practices (Abell & Bryan, 1997; Gess-Newsome, 2002a), there is evidence that science teacher preparation programs around the world are devoting a small portion of their curricula to science pedagogy courses aiming to developing teachers' PCK (Cofré et al., 2015; Pedersen et al., 2017). This is why it is critical for science teacher preparation programs to place an emphasis on the science pedagogy courses, especially in those programs where these courses represent less than 15% of the curriculum.

Practicum experiences in science teacher education

Practicum experiences are defined as a school-based initiation to professional practice that is supervised by schoolteachers and university supervisors. They have the potential to help student teachers to further develop their PCK, CK and PK. Some instructors and researchers have included a practicum component in their SMCs or a field experience component in the case of field-based methods courses (Bayraktar, 2009; Crawford et al., 2005; Eick et al., 2003; Seung et al., 2019; Yerrick & Hoving, 2003).

There is a great variation in the practicum experiences in terms of the extension and models in different science teacher preparation programs around the globe. Some countries have early practicum experiences, like Finland

(Evagorou et al., 2015; Pedersen et al., 2017), Germany (Neumann et al., 2017), and Canada (Olson et al., 2015; Pedersen et al., 2017; Tippett & Milford, 2017), and it can start as early as in the first year, like in some programs in Chile (i.e., Universidad Metropolitana de Ciencias de la Educación). The practicum experiences range between 5% and 20% of the science teacher preparation programs' curriculum in most countries. They can represent as little as 5% or less of the curriculum in countries like Slovenia (Štemberger, 2020; Valenčič & Vogrinc, 2011) and Macau (Liu & Liu, 2017). The former has a really strong focus on science in their curriculum (80%), and the latter has an average of 86% of courses in general pedagogy and science content (52% and 34% respectively), which can explain the lack of emphasis on the practicum experiences. Special is the case of South Africa (Taylor et al., 2019), where practicum experiences can represent up to 27% of the curriculum. The typical length of the science teacher preparation programs is four years, and the practicum ranges between 10 to 35 weeks total, with a final teaching internship of 10 to 12 weeks. In their internship, student teachers are supervised by a university and a school supervisor, although this is not always the case.

Diversity in The Science Methods Courses

Published papers on science methods courses show the great diversity of approaches in these courses. They have also been offered in multiple formats, such as face to face, online, school-based, summer camp-based, and they have been used with different purposes in science teacher preparation. Below is a review of the different approaches that have been used in elementary, middle and secondary science methods courses.

Selection of studies for the review

The purpose of this review is to map out the diversity of approaches that can be found in the literature when it comes to design and implement science methods courses. For this purpose, I conducted a literature search on EBSCOhost through the university library. I searched papers between 2000 and 2021 with the keywords "science methods course*" in the title and published in peer-review journals. The initial results list contained one hundred and twenty-five articles. From this list, I selected papers where a particular approach or topic was implemented and studied in the context of a SMC (either elementary, middle or secondary SMCs), and researchers evaluated the impact of that particular approach or topic on pre-service or in-service elementary, middle school or secondary science student teachers. From the initial list of results, twenty-four articles were selected for this review (**Error! Reference source not found.**).

Analysis of studies

The selected papers were mainly reviewed to understand (a) the particular approach that was implemented or foci of the science methods courses, and (b) the impact that the particular approaches in the SMC had on student teachers' understanding or practices.

Table 1 *Summary of studies with diverse approaches/ emphasis implemented in science methods courses.*
(*SMC: Science methods course; PST: Pre-service teachers; IST: In-service teachers; PSST: Pre-service science teachers; ISST: In-service science teachers; NOS: Nature of science; EE: Environmental education; VR: Virtual reality; CT: Computational thinking; GCC: Global climate change; GW: Global warming; SSI: Socio-scientific issues; PBL: Problem-based learning; PCK: Pedagogical content knowledge; SPS: Science process skills; SL: Scientific literacy; STS: Science/ Technology/ Society; AST: ambitious science teaching; CRP: Culturally relevant pedagogy/ teaching)*

Author (year)	**Context (Elem, Middle, Sec)**	**Approach or emphasis of the SMC**	**Participants (n)**	**Results**
Plevyak (2007)	Early childhood SMC	Inquiry-based curriculum	Early childhood (PreK-3) PST (52)	Teachers' understanding and confidence of how to implement inquiry deepened
Seung et al. (2019)	Summer camp-based elementary SMC	Summer camp teaching component (teachers taught K-6 children for their practicum requirement)	Elementary PST (55)	Teachers' self-efficacy in teaching science as inquiry increased significantly as a result of participating in the SMC
Weiland and Morrison (2013)	Elementary SMC	Integration of EE with an experiential reflective approach (course 1: science content focus [i.e., sustainability] and course 2: method focus [i.e., problem-based learning])	Elementary PST (31)	Both courses helped teachers in building EE content, envisioning EE in their future classrooms, and promoting EE as a context for integrating their instruction.
Hestness et al. (2011)	Elementary SMC	Curricular module on global climate change (integrated science, tech, and math, inquiry, science for all and active learning)	Elementary PST (candidates) (63)	Module had a potential positive impacts on teachers' understanding of global climate change, confidence to teach, and awareness of resources.

Harron et al. (2019)	Elementary SMC	VR and in-person field trips to a local natural history museum	Elementary PST (27)	Teachers value the use of VR in science class in different situations (inaccessible or unsafe locations, to explore scales of size, to witness different events at varying temporal scales)
Gado et al. (2006)	Elementary SMC	Integration of mobile technology (handheld-computers and probeware)	Elementary PST (21)	Teachers improved their inquiry abilities, organizational skills, and engagement in science content learning, in addition to self-efficacy.
McGinnis et al. (2020)	Elementary SMC	Curricular module on CT	Elementary PST (39)	Teachers supported the integrating CT in their science teaching; they appreciated that CT made science engaging for young learners; and, they believed that CT supported the implementation of good science teaching practice.
Morrison (2008)	Elementary SMC	In-depth individual inquiry investigation	Elementary PST (39)	Teachers demonstrated a variety of strengths in their understandings of inquiry-based teaching, their attitudes towards doing science, and their projected use of inquiry in their own classrooms
Santau et al. (2014)	Elementary SMC	Focus on science content through modeled inquiry-based pedagogy.	Elementary PST (19)	Teachers improved on moderate and difficult science content knowledge
Gess-Newsome (2002b)	Elementary SMC	Explicit focus on NOS and science inquiry	Elementary PST (30)	Teachers' definitions of science became more sophisticated
Matkins and Bell (2007)	Elementary SMC	Explicit NOS instruction within GCC and GW topics.	Elementary PST (15)	Teachers' conceptions of NOS and GCC/GW improved, and they were able to apply their conceptions to decision making about SSI.
Akerson et al. (2014)	Elementary SMC	Four different contexts: NOS theme about teaching science and NOS; explicit-	Elementary PST (62)	All teachers improved in their conceptions of NOS in all four contexts, and they were able to describe strategies for

		reflective NOS teaching approach; PBL to teach NOS; and NOS embedded into Authentic Inquiry		teaching NOS by context.
Riedinger et al. (2011)	Elementary SMC	Integration of informal science (guest speakers, live animal demonstration, virtual field trip)	Elementary PST (treatment: 72; comparison: 26)	Teachers in both groups improve their attitudes and beliefs towards science, but only teachers in the treatment group incorporated informal science in their lesson plans.
Kelly (2000)	Elementary SMC	Constructivist approach and focus on improving PCK	Elementary PST (230)	Teachers presented more positive attitudes towards science and science teaching and expressed greater confidence in their ability to teach science.
Bayraktar (2009)	Elementary SMC	Included teaching and assessment strategies, SPS, student misconceptions, modeling and a practicum-like component	Elementary PST (124)	Teachers' science teaching efficacy beliefs and attitudes toward science improved through the course period
Cormas (2017)	Integrated elementary mathematics/ science methods course	Integration of science and math activities (science inquiry lesson on biological classification and mathematics problem-solving lesson on polyhedra)	Elementary PST (39)	Teachers were able to recognized epistemological differences between math and science.
Atasoy and Cakiroglu (2019)	Elementary & Middle School SMC	Group work and collaboration for lesson planning + microteaching	Elementary PST (4)	Teachers' collective efficacy improved over the semester
Black (2006)	Elementary & secondary SMC	Emphasis on SL, SPS, K-12 science curriculum and, teaching strategies (guided inquiry, reading/ writing in science, field experiences)	Elementary PST (22) and secondary PSST (25)	elementary students maintained their NOS views while secondary students significantly lower their NOS views.

Mensah et al. (2018)	Graduate elementary SMC and graduate secondary science induction course	Focus on CRP and approaches for integrating multicultural content into teaching (Banks's typology)	Elementary PST (20) and secondary ISST (12)	Teachers' post-lesson conceptions were a mixture of optimism and under-preparedness to label themselves culturally relevant teachers.
Dass (2005)	Secondary SMC	STS approach	PSST (18) and ISST (3)	Teachers were willing to use the STS approach with their own students, but few expressed confidence in their ability to do so.
Stroupe and Gotwals (2018)	Secondary SMC	Focus on AST	PSST (17)	Teachers developed macroteaching over time, improved their understanding of complexity of AST.
Yerrick and Hoving (2003)	Secondary SMC	Focus on reflections on their own science teaching practice and engagement in equity issues.	PSST (-)	Some teachers reflected on and revised their practices and produced new knowledge (producers) and others were resistant to shift their thinking and reproduced their own educational experience (reproducers)
Eick et al. (2003)	Secondary SMC	Implemented a situated learning model of coteaching in the context of the field experience component	PSST (10)	Four positive outcomes for PSTs: comfort in learning to teach; critical reflection in modeling the teacher's lesson; development of confidence in teaching and managing students; and positive effect of seeing and doing inquiry in practice.
Crawford et al. (2005)	Secondary SMC	Use of technology and inquiry-based tasks (software "The Galapagos Finches")	PSST (21)	Most teachers improved their understandings of evolutionary concepts through metacognition, and some others improved their NOS understandings

Varied approaches on science methods courses

The science methods course seems to be a very versatile course in science teacher preparation. Different instructors and researchers have implemented different approaches in these courses, in terms of the goals, contents and format of these courses. Many of these decisions were well aligned with the researchers' interest and background in many cases. In terms of formats, these courses have been implemented online, in person, and some of them have included a practicum or field experience component in the case of field-based methods courses (Bayraktar, 2009; Crawford et al., 2005; Eick et al., 2003; Seung et al., 2019; Yerrick & Hoving, 2003). For instance, Seung et al. (2019) developed a summer camp-based methods course for elementary preservice teachers. The purpose was to prepare teachers to create effective science learning environments and to increase their self-efficacy in teaching science as inquiry. It was a four-week long course that utilized a summer camp offered for students in kindergarten through six grade. The first two weeks the preservice teachers learned about inquiry based, learning theories, science instructional models, technology in science teaching and lesson planning. The following two weeks preservice teachers were divided in groups and asked to teach the summer camp participants. Each preservice teacher was required to develop and teach inquiry-based lessons including hands-on activities. Three experienced teachers supervised modeled inquiry-based teaching for the preservice teachers. By the end of the course, preservice elementary teachers' self-efficacy in teaching science as inquiry increased significantly as a result of participating in the SMC, according to the changes in the Teaching Science as Inquiry (TSI) survey.

Inquiry-based orientation has been a common approach for science methods courses from early childhood SMC (Plevyak, 2007) to secondary SMC (Crawford et al., 2005), but especially in elementary SMC (Gess-Newsome, 2002b; Morrison, 2008; Santau et al., 2014). These inquiry-based SMC have had different purposes, improving teachers' understanding and confidence on implementing inquiry teaching (Morrison, 2008; Plevyak, 2007), improving their attitudes towards doing science (Morrison, 2008), their science content knowledge (Santau et al., 2014), their nature of science views (Black, 2006; Gess-Newsome, 2002b), among others. For instance, Santau et al. (2014) designed an elementary SMC focus on teaching science content through modeled inquiry-based pedagogy. It was a 17-week long course, with a peer teaching component at the end. The course was designed to help preservice elementary teachers to develop: a theoretical framework for teaching science through inquiry, a repertoire of inquiry-based methods for teaching science to students in Pre-K through fourth grade, and a deeper understanding of science content used to model inquiry-based methods. The lessons were designed following a modified augmented version of the 5E instructional model and levels of inquiry. Instructors altered the sequence of Es in some cases, embedded explanation into all other Es, and provided multiple examples for each E during a single lesson. Preservice teachers engaged in 12 varied inquiry-based and content-based activities. The lessons were designed to meet various levels of inquiry (1-3) and instructors explicitly avoided presenting content prior to activities and allowed students to discover the content through the exploration. The course covered topics in four content areas: earth science, life science, physical science, and the nature of science (embedded). Some of the topics discussed were biomes, animal and plant adaptations, body systems, electrical circuits and magnetisms. By the end of the course, preservice teachers improved their understandings of moderate and difficult science contents according to the science knowledge test designed by the authors.

Various authors have incorporated the nature of science (NOS) aspects into their SMC (Akerson et al., 2014; Black, 2006; Gess-Newsome, 2002b; Matkins & Bell, 2007). Most of these courses have followed an explicit approach to teaching NOS. This concept has been taught along with scientific inquiry (Gess-Newsome, 2002b), embedded in socio-scientific issues (Matkins & Bell, 2007), and using different contexts. With the purpose of determining how varied contexts could improve elementary preservice teachers' conceptions of NOS and their ideas for teaching NOS, Akerson et al. (2014) adapted four elementary SMCs at the same university and implemented a different context of NOS instruction in each of them. The first context was "NOS theme" in which all the course activities focused on the teaching and learning of NOS. The second context was "reflective NOS teaching", in which preservice teachers had explicit and reflective NOS practices during portions of the semester. The third context was "problem-based learning", in which instructors selected local problem science scenarios to teach NOS with an explicit and reflective approach. And the fourth context was " NOS embedded into Authentic Inquiry", in which the learning of NOS was embedded in a long-term science investigation. Researchers found that all preservice teachers improved their NOS understanding in all four contexts, with some differences in the specific NOS aspects considered in the study, and they developed ideas for strategies for teaching NOS. In another study, Matkins and Bell (2007) taught NOS within the context of global climate change and global warming (GCC/GW) topics in an elementary SMC. The authors wanted to assess the influence of explicit, contextualized NOS instruction on preservice elementary teachers' understanding of NOS and GCC/GW. A portion of this class was devoted to specific instruction on NOS, where the activities included explicit references to different NOS aspects. In one of these activities, students went outside and made observations of clouds and measured some climatic variables (ambient temperature, atmospheric pressure, and relative humidity), and the instructor emphasized the importance of observation in science and the tentative nature of scientific knowledge. Another interesting activity in this course were meetings with scientist. Here, each student team was assigned to a mentor, who was a faculty in the department of environmental science. They met twice in the semester to gain an understanding of the current research on GCC and GW, and to discuss how to translate these concepts into lessons for elementary students. After instruction, participant teachers had substantial improvements in their NOS views, and a large portion of the class changed their ideas on GCC/GW and NOS in the right direction.

A focus on the integration of technology is also a common approach in the design of SMC (Crawford et al., 2005; Gado et al., 2006; Harron et al., 2019; McGinnis et al., 2020). Technology has been integrated with different purposes in

SMC, like improving the value that teachers attribute to the use of technology in the classroom (Harron et al., 2019; McGinnis et al., 2020), improve their understanding of science (Crawford et al., 2005) and engagement (Gado et al., 2006) with science contents. For instance Crawford et al. (2005) developed a secondary SMC where preservice secondary science teachers had the opportunity to utilize *The Galapagos Finches* software-based instructional materials. This course had a practicum component in middle and high school classrooms. Instructors emphasized the importance of using appropriate software in supporting children's learning about scientific inquiry. The software provides students with data sets of physical and behavioral characteristics of finch population from the Daphne Major in the Galapagos. Students engage in using the data sets to build explanations, similarly to what scientist do. Following instruction, most participants improved their understanding of evolutionary concepts, and some others improved their understandings of NOS.

Researchers and instructors have also been incorporating diversity, equity and inclusion issues in their SMC (Mensah et al., 2018; Yerrick & Hoving, 2003). For instance, Mensah et al. (2018) designed a graduate elementary SMC and graduate secondary science induction course. Some common aspects between these two courses are the purpose of developing affirming attitudes toward culturally diverse students, introducing sociopolitical connections into science instruction and reflection on how multicultural science education tenets can be applied to their own professional contexts. Both groups participated in a lesson on culturally relevant teaching with a focus on multicultural education theory with some practical examples. Only in-service science teachers were asked to design science units that were culturally relevant to the students and communities. In the case of the secondary SMC, in-service secondary teachers expressed their need for more knowledge and support, which indicate a mixture of optimism and underpreparedness as culturally relevant science teachers. In the case of the elementary SMC, pre-service elementary teachers expressed seeing themselves as culturally relevant science teachers and they recognized interdisciplinary connections as an instrument in transforming the curriculum and as a characteristic of being a culturally relevant science teacher.

Some other interesting approaches considered in SMC are the integration of informal science to improve attitudes toward science and encourage the use of informal science in the classroom (Riedinger et al., 2011), the integration of science and math activities for preservice elementary teachers to help teachers to recognized epistemological differences between math and science (Cormas, 2017), a focus on Science/ Technology/ Society (STS) issues to encourage students to incorporate this approach in their practices (Dass, 2005), and a focus on ambitious science instruction (AST) (Stroupe & Gotwals, 2018), among others (see **Error! Reference source not found.**).

Research of the impact of different approaches of science methods courses on teachers' learnings

Science methods courses seems to be a key component in science teacher preparation given the multiple dimensions of teachers' learning that can be supported during these courses. These courses have been offered in multiple formats. The most common is the traditional SMC offered in-person on-campus. Some of them have also been offered online, especially during the pandemic. Also many SMC include a practicum or field experience component (Bayraktar, 2009; Crawford et al., 2005; Eick et al., 2003; Seung et al., 2019; Yerrick & Hoving, 2003) which could be microteaching or peer teaching demos, teaching at a partner school, or teaching at a summer camp.

These types of interventions are more common in the context of elementary SMC. Out of 24 studies considered in this review, 19 of them were conducted in the context of early-childhood or elementary SMC, and 16 were conducted exclusively in elementary SMC. Seven of these studies were conducted in the context of secondary a SMC, and one of them in middle-school SMC. Also, the participants of these interventions were mostly pre-service teachers. Out of the 24 studied considered, 19 included pre-service teachers (elementary or middle school), and 6 considered pre-service secondary science teachers. Only two studies considered in-service secondary science teachers as participants.

Researchers have evaluated the impact of these courses on different teachers' variables. For instance, several studies have explored teachers' understanding and practices related to scientific inquiry (confidence of how to implement inquiry, self-efficacy in teaching science as inquiry) (Eick et al., 2003; Gado et al., 2006; Morrison, 2008; Plevyak, 2007; Seung et al., 2019). In some cases, these studies included an explicit emphasis on scientific inquiry and strategies to teach science using this approach (Morrison, 2008; Plevyak, 2007), but that was not always the case. Among the different approaches implemented in the SMC to improve teachers' understanding and practices related to scientific inquiry are the use of a situated learning model of co-teaching during the field experience component of the curse (Eick et al., 2003); the integration of mobile technology (Gado et al., 2006), and the implementation of practicum component in the context of a summer camp (Seung et al., 2019). Generally, these studies reported positive outcomes, like improvements in teachers' understandings of inquiry-based teaching (Morrison, 2008; Plevyak, 2007), their projected use of inquiry in their own classrooms (Morrison, 2008), or confidence of how to implement inquiry (Plevyak, 2007). According to these results, there are multiple approaches and practices that can be implemented in the context of SMC to improve teachers' understanding and practices related to scientific inquiry.

SMC has also been the context to improve teachers' content knowledge (Crawford et al., 2005; Hestness et al., 2011; Matkins & Bell, 2007; Santau et al., 2014; Weiland & Morrison, 2013), and NOS understanding (Akerson et al., 2014; Black, 2006; Crawford et al., 2005; Gess-Newsome, 2002b). For instance, to improve teachers' understanding of evolutionary concepts (Crawford et al., 2005), global climate change and global warming (Hestness et al., 2011; Matkins & Bell,

2007) or environmental education related topics (i.e., sustainability) (Weiland & Morrison, 2013). Some of these studies also looked to improve teachers' confidence to teach science contents (Hestness et al., 2011; Kelly, 2000). Most of these studied reported positive outcomes on teachers' content knowledge, with some exceptions (Black, 2006).

Additionally, SMC has also been the context to improve teachers' attitudes and beliefs toward science and doing science (Bayraktar, 2009; Kelly, 2000; Morrison, 2008; Riedinger et al., 2011). This have been achieved through different approaches, like a constructivist approach with a focus on improving PCK (Kelly, 2000), in-depth individual inquiry investigation (Morrison, 2008), or integration of informal science (Riedinger et al., 2011). These studies reported positive outcomes on teachers' attitudes and beliefs toward science.

Some other teachers' variables improved in the context of different SMC has been (a) the value that teachers attribute to the use of technologies for teaching science, through the use of VR and in-person field trips to a natural history museum (Harron et al., 2019) or through the implementation of a computational thinking module (McGinnis et al., 2020); (b) teachers' collective and self-efficacy (Atasoy & Cakiroglu, 2019; Bayraktar, 2009; Gado et al., 2006), through group work and collaboration for instance (Atasoy & Cakiroglu, 2019) or through the integration of mobile technology (Gado et al., 2006); (c) teachers' confidence to use science/ technology/ society (STS) approach, through the implementation of a STS approach in a secondary SMC (Dass, 2005); (d) teachers' understanding of ambitious science teaching (AST) in a secondary SMC with an emphasis on this framework (Stroupe & Gotwals, 2018); (e) teachers' perceptions as culturally relevant teachers in an elementary and secondary SMC with an emphasis on culturally relevant pedagogy (CRP) (Mensah et al., 2018); (f) other teachers' teaching practices (Yerrick & Hoving, 2003).

Concluding thoughts

The SMC seems to be a good context for the implementation of multiple approaches that are relevant for science teachers and has the potential to impact on multiple teachers' variables. According to the results of this review, most of the studies have been conducted in the context of elementary SMC, and most of the times the participants of these studies were pre-service elementary teachers. These findings suggest a lack of explicit emphasis on studying the impact of different approaches on teachers' variables in the context of middle school and secondary SMC. Additionally, the participants of the reviewed studies were mostly pre-service teachers. This suggests a lack of attention to the learnings and practices of in-service science teachers in the context of SMC. This could be explained because the SMC are more commonly offered during initial teacher preparation than in graduate school or professional development programs for in-service teachers.

Between the most common approaches implemented in the SMC are an inquiry-based orientation, an emphasis on NOS and a focus on the integration of technology. In the case of the inquiry-based orientations, this approach is especially common in the context of elementary SMC. Also, a focus on improving teachers' content knowledge is very common in elementary SMC. Some less common approaches implemented in SMC are the integration of informal science, integration of science and math, a focus on STS, AST, and CRP. Because of this diversity of approaches that can be implemented in SMC and the potential of these approaches to impact on multiple variables of teachers' learning, SMC can contribute to multiple dimensions of teachers' PCK.

An implication for research is the need for more studies in the context of middle school and secondary SMC, and the inclusion of more middle school and secondary teachers as participants in these studies. Additionally, it is necessary to conduct more studies that explore the impact of less common or less traditional approaches in SMC (i.e STS, AST, CRP) on science teachers' understandings and practices, and on the multiple dimensions of teachers' PCK.

CHAPTER 3

3. METHODS

Participants and Selection Criteria

The **participants** of this study are 10 prospective science teacher educators (PSTEs) in different stages of their doctoral programs in science education or science curriculum and instruction from three universities, who voluntarily agreed on participating in this research. Some of them have been admitted to candidacy, while some others are completing the coursework, and they have taken different graduate courses so far. They have different science backgrounds (biology, chemistry, physics, and astronomy), and they have teaching experience in different school levels (elementary, middle, and high school). Also, participants are originally from six different countries (two from Turkey, one from India, one from Vietnam, one from China, one from Taiwan, and six from the United States). For six of them, English is their second language. This diversity in their backgrounds facilitates a *cross-case item analysis* of the studied variables.

Participants in the study come from 3 different universities in the USA. Most participants come from a large university in the southeast region. They are in a Ph.D. in science education. This program requires at least 3 full-time years of science teaching experience, and they need to take at least 22 cr. of science education courses, as well as a number of credit hours of science content courses equivalent to a master's degree. Some of the exit requirements are a sole- or first-authored manuscript for publication, as well as a conference presentation proposal. One participant comes from another big-size university in the southeast. This participant is enrolled in a Ph.D. in curriculum & instruction with a concentration in science education. This program requires doctoral students to take at least 9 cr. of science ed. courses and 9 cr. of science content courses. Doctoral students in this program are encouraged to teach at least one course during their program and/or supervise pre-service teachers for at least one semester. One more participant comes from a mid-size university in the southeast region. This participant is pursuing a Ph.D. in math and science education with a concentration in biological education. This program requires 18 cr. of concentration core courses (biology content courses) and 30 cr. of core courses (including here science ed. and math ed.). Doctoral students are also required to have at least two research presentations at national or international meetings, and be the lead author or coauthor of two articles published, or under review in peer-reviewed journals.

See **Table 2** for more details about participants' backgrounds from the three cases.

The **selection criteria** were:

1- Participants pursuing doctoral degrees in science education or related doctoral programs.

2- Participants interested in teaching any type of science methods courses in the future (elementary, middle, or high-school SMC).

Table 2 *Participants' background and teaching experience.*
(*SMC: Science methods course, TA: Teaching Assistant*)

	Background	**Year in their Ph.D.**	**Country**	**Took SMC**	**Taught or TA SMC**	**Years of K-12 teaching experience**	**Subjects taught in K-12**
			Elementary Case Participants				
E1	Ecology	1st	United States	Yes	No	5	Biology, Environmental Science, Scientific Research.
E2	Biology/ Genetics and Biotechnology	3rd	United States	No	No	0	-
E3	Chemistry	2nd	Taiwan	Yes	Yes	2.5	General Science, Chemistry, Physics, Biology, Health Education, Music
E4	Biology	5th	United States	Yes	Yes	18	Life, Physical, Environmental, Earth and Marine Sciences, Chemistry, Math, Anatomy and Physiology, Ecology, Botany.
			Middle School Case Participants				
M1	Chemical Engineering	4th	India	Yes	No	15	General Science, Chemistry, Physics.
M2	Science	1st	Turkey	Yes	Yes	3	General Science
M3	Elementary Education	4th	United States	Yes	Yes	3	Earth and Space Science, General Science, Reading.
			Secondary Case Participants				
S1	Physics	2nd	China	Yes	No	0.5	Physics
S2	Biology	3rd	Turkey	Yes	Yes	2.5	Life and Physical Sciences
S3	Biology	1st	Vietnam	No	No	10	Biology, Chemistry, Physics, Math

Sampling and Recruitment

Participants were selected through *purposeful comparison-focused sampling*, in particular, *matched comparison* (Patton, 2015). In purposeful sampling, the researcher selects information-rich cases for in-depth study. These are cases from which you can learn about the phenomena of interest. (Patton, 2015). Comparison focused sampling is when researchers "select cases to compare and contrast to learn about the factors that explain similarities and differences" (Patton, 2015, p. 405). Finally, in matched comparison, the researcher compares "cases that differ significantly on some dimension of interest to understand what factors explain the difference" (Patton, 2015, p. 405). The diversity of the group of participants facilitated the comparisons.

Participants were invited to participate through email and social media. A flyer with the selection criteria was posted on Tweeter and Facebook profiles of science education associations. Twelve doctoral students were interested in participating in the study, and ten completed all the tasks.

Study context

The **context** for data collection in this study was an online consultation program designed to guide PSTEs in the design of a science method course. The online consultation took place in four one on one 45-90 minutes sessions with each participant. The sessions were held over Zoom, and some of them were recorded and transcribed in Otter.Ai. During this process, participants participated in different activities to engage them with the design of a SMC and they completed different tasks required for each session. Before the first session, they were asked to complete a background questionnaire. **Table *3*** provides a summary of the consultation sessions.

Table 3. Summary of activities of the online consultation.

Session 1 *- Crafting a Teaching Philosophy Statement (TPA)*
During the first session, participants were introduced to the concept of a teaching philosophy statement, especially those that were not familiar with it. They were provided with different strategies for creating a TPA, like the use of metaphors for visualizing their beliefs about teaching. Also, they were provided with different models or structures of TPAs, and with some guiding questions to get them started with their own TPA. After this session, participants were asked to create a TPA before moving to the next session. *Data sources generated from this session*: TPA
Session 2 *- Thinking aloud about the science methods course*
During this session, participants were first asked to define some essential characteristics of the SMC they wanted to design, like the level of this course (elementary, middle or secondary methods course), if they wanted to include science content or not, the context for this course (country), if it was going to be an undergraduate or graduate class, among others. Then they were asked to write a draft of the general aims or expected outcomes for this class. After this, we moved to the think-aloud portion, where they were asked to brainstorm on some general areas and topics they wanted to include in their course. During this process, they created a concept map with the topics they considered relevant for their SMC. I occasionally interrupted with some follow-up questions. When they finished the concept map, they were asked to place in the same concept map some of the potential assignments they wanted to include in this course. A purpose of this session was to get them started with the design of their syllabus. After this session, participants were asked to finish their science methods syllabus before moving to the next session. *Data sources generated from this session*: Audio record of the think-aloud task, the outline of topics and assignments (concept map), and the SMC syllabus.
Session 3 *- Reflection on the design process of the science methods course*
During this session, participants were asked to create a visual representation of the process they followed for designing their SMC. During this process, I asked some guiding questions to help them to create this process map. After this, I asked them to explain and reflect on this process map, and I asked follow-up questions from a semi-structured protocol to help them to think deeply in the process. After this session, they were asked to provide a written reflection about this process. *Data sources generated from this session*: Audio record of the oral reflection, process map, written reflection.
Session 4 *- Final Interview*
This was a semi-structured interview. For this interview, I brought the SMC syllabus and preliminary findings of their process for designing the syllabus. For member checking purposes, I asked them how accurate these findings were, and I asked them to suggest modifications if they considered it was necessary. After this, we continued with questions from a semi-structured protocol with the aim of illuminating and confirming the preliminary findings, filling some gaps in the data, and delving into the whole process of designing a SMC and into potential factors influencing this process. *Data sources generated from this session*: Audio record of the final interview.

Type of qualitative design

The study followed an ***embedded, multiple case study research design*** (Yin, 2018). In embedded multiple-case design, each individual case contains embedded units of analysis. Multiple case study design facilitated the understanding of the individualities and the differences in the nature of the three studied cases. Consequently, I organized participants in these three cases, according to their preferences: the design process of science methods courses for elementary (four participants), middle school (three participants), and secondary (three participants) level. The embedded units within each case are the PSTEs, who developed SMC for each school level. Within each embedded unit of analysis, three sub-units of analysis are considered: topics considered by PSTEs when designing a SMC; challenges they face during this process; and potential factors influencing their decisions. **Figure *4*** summarizes this research design.

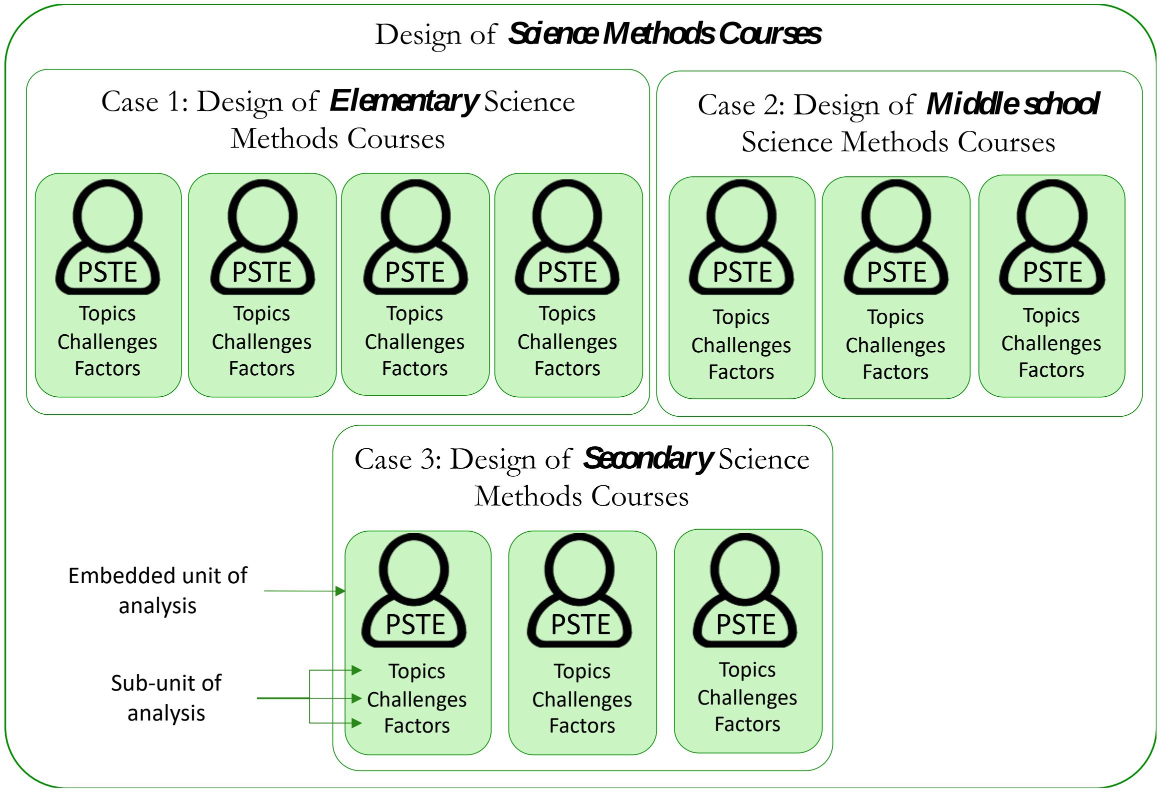

Figure 4. Embedded multiple case study research design.
(*PSTE: Prospective science teacher educator*)

A rationale for the use of multiple case design is the possibility of conducting literal and/or theoretical replications (Yin, 2018). Due to the diversity of the group of participants (different stages in their PhDs, elementary, middle, and high school focus, different science backgrounds), it is possible to conduct both types of replications. In *literal replications*, the researcher predicts similar results because of the similarity of conditions or contexts (Yin, 2018). In this research project, I expect to *conduct literal replications* between PSTEs with a similar background and stage in their PhDs and interested in similar school levels (K-12). In *theoretical replications*, one or two variables are different and could provide contrasting results (Yin, 2018). In this research project, I expect to conduct *theoretical replication* by contrasting PSTEs with different backgrounds, stage in their PhDs, and interested in different school levels (k-12).

Data Sources

Artifacts analysis*:*

Different artifacts developed by the PSTEs were analyzed: their science methods course syllabus, a process map, and a reflection paper. These artifacts were developed throughout the course of the online consultation. **Table *4*** provides a summary of these artifacts.

Table 4. Summary of artifacts to be used as data sources.

Artifacts	Description
Artifact 1: *Background questionnaire*	An online survey about participants' education, experiences, and other background information. It contained 26 items, and it was delivered using Qualtrics. (It helped to identify some potential factors influencing on the decisions they make on their science method courses)
Artifact 2: *Syllabus*	Participants were asked to design a syllabus for a SMC. They had total freedom for designing this course (course school level, contents, activities, assignments, etc.) (It helped to identify the dimensions/topics considered by each participant).
Artifact 3: *Reflection paper*	A reflection on the process of designing a SMC. Some guiding questions were provided. (This could potentially contribute to all the research questions).

Audio recordings of sessions:

Some of the sessions of the online consultation were audio recorded. The audio recordings were transcribed using Otter.ai and analyzed using the same approach applied to the other data sources. Discussion and reflection were essential components of the sessions. A ***think-aloud interview*** was conducted in session two. In this type of interviews, "while someone engages in an activity, the interviewer asks questions and probes to get the person to talk about what he or she is thinking as he or she does the task" (Patton, 2015, p. 711) with the purpose of eliciting "inner thoughts... that illuminate what's going on in a person's head during the performance of a task" (Patton, 2015, p. 711). In this case, the task was to create a concept map with the topics they considered relevant to include in a SMC. An *oral reflection* was conducted in session three, where participants were asked to create a visual representation of their process of designing a SMC, and then they were asked to reflect on it. **Table *5*** summarizes the two recorded sessions.

Table 5. Audio recordings used as data sources.

Audio recordings	Description
Think-aloud interview	Participants were asked to brainstorm on some areas or topics they wanted to include in their SMC. Then they were asked to create a concept map for organizing these topics. During this process, I asked them to "think aloud." I occasionally interrupted with follow-up questions.
Oral reflection	Participants were asked to create a visual representation of the process they followed for designing their science methods syllabus. Based on this diagram, they were asked to reflect on their process for designing the course. I asked some guiding questions during this process.

***Semi-structured interviews**:*

Another method for collecting data from the participants was semi-structured, individual, face-to-face interviews (Brinkmann, 2013). The semi-structured interviews were conducted in the last session with the participants. In a semi-structured interview, there is an interview guide with some questions and topics that the researcher needs to address, and usually, the questions are open-ended (Roulston, 2010). Also, in semi-structured interviews, the interviewer follows up with probes in response to the interviewee's answers in order to get a more in-depth and more detailed description of what the interviewee said on the studied phenomena (Roulston, 2010). One of the advantages of an interview guide approach is that data collection is made systematically for each participant; thus, the researcher obtains information for a complete set of topics for each participant allowing the comparison between responses (Patton, 2015). For this reason, I used a basic template of an interview guide for each participant, to ensure that a common set of topics are being addressed, but at the same time, these interview guides were tailored for each participant, based on the survey, the syllabus and the rest of the artifacts they generated through the consultation. During this final interview, I conducted ***stimulated recall***. In stimulated recall, participants are confronted with videos, audio playback, pictures, or any other representation of their experiences or realities, with the purpose of getting participants to relive or re-experience a situation to understand better what determined their actions (Mills et al., 2010). In this study, stimulated recall was achieved by confronting STEs with some of the artifacts they developed with the purpose of helping them to remember and reflect on their process of designing a SMC. **Figure *5*** summarizes the overall research design of this project for one case. The same design is applicable to the other two cases.

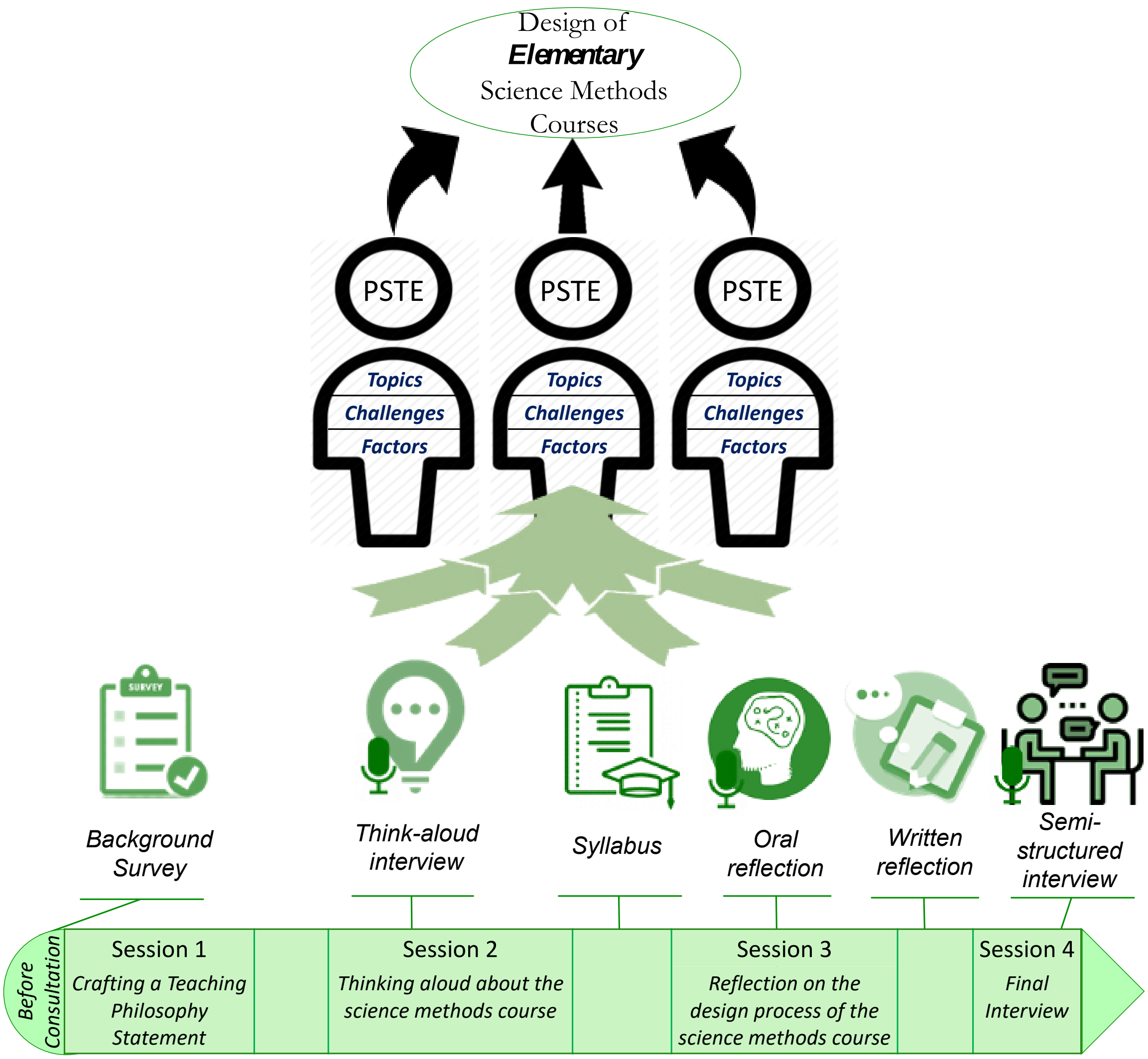

Figure 5. Overall research design and data sources (same design for middle school and secondary science methods course designs).
(*PSTE: Prospective science teacher educator*)

Data management

Data were managed using NVivo 12 to facilitate the management and analysis of multiple data sources. All the participants were associated with a pseudonym, and it was used in the survey, concept and process maps, science methods course syllabus, reflection paper, and in the transcriptions of the recorded sessions and interviews. This allowed me to connect participants' responses from the different data sources. Within a period of 30 days after data was collected, all real names were replaced in the oral and written data sources during the transcription and/or digitalization process. Any other identifying information was modified, replaced, or deleted in order to ensure anonymity of participants. All digital files (written documents, audio files) were saved in a password-protected computer, and only researchers working in the project had access to these documents. All files were deleted after the analysis is complete at the conclusion of the project. All the data collection related documents were labeled with information about the name of the researcher responsible for collecting that data, date, time, and place of data collection, and the pseudonym of the participant. For the interview transcriptions, (I) was used for 'interviewer' and (R) for the 'responder' or 'interviewee.'

Data analysis

The data was analyzed through ***thematic analysis*** (Guest et al., 2012). Thematic analysis is a systematic approach that focuses on identifying and describing key themes (implicit and explicit) from textual data through the development of codes (Guest et al., 2012). The codes were created following deductive and inductive approaches. In the ***deductive approach***, "a provisional list of codes should be determined beforehand… to harmonize with your study's conceptual framework, paradigm, or research goals" (Saldaña, 2015, p. 75). Thus, the qualitative *deductive analysis* consists of "determining the extent to which qualitative data in a particular study support existing general conceptualizations, explanations, results, and/or theories" (Patton, 2015, p. 541). Most of the codes were based on the Professional Knowledge Bases from the refined consensus PCK model (RCM) (Carlson & Daehler, 2019) and the PCK dimensions from the pentagon model (Park & Oliver, 2008a) (**Appendix A** includes criteria of inclusion), plus other codes that are relevant to this study (i.e., challenges, factors). Keeping in mind the idea of '***emergent coding***' (or inductive coding) (Drisko & Maschi, 2016), some of the codes and sub-codes were created from the data, as *emergent codes*. Based on these codes, a thematic network (Bazeley, 2013) was constructed. **Table *6*** explain the coding process step by step. **Figure *6*** summarizes this process.

Also, a ***cross-case item analysis*** was conducted, where the analysis focuses on analyzing patterns across different data collection procedures (Patton, 2015); in this case, the analysis focused on the professional knowledge bases dimensions from the RCM (Carlson & Daehler, 2019) and the PKC dimensions from the pentagon model (Park & Oliver, 2008a). Here I compared participants with and without prior experience teaching or teaching assisting a SMC, or the number of years in the Ph.D. program, among other differences identified in the group of participants. This analysis yielded some potential factors influencing PSTEs' PDM on their designed SMCs.

Table 6. Step by step coding process.

Coding phase	Description
First cycle coding	Initial deductive and inductive coding. This first cycle and the following cycles were conducted in NVivo 12 since it facilitates the management and analysis of multiple data sources.
Post-coding transition phase	During this phase, I generated the complete code-book, including the deductive and inductive codes. Then I refined the definitions and inclusion criteria for the codes based on the first cycle coding.
Second cycle coding	I went through the data again and re-coded some of the previous codes, especially the inductive codes, which do not have a pre-established definition or inclusion criteria during the first cycle coding. Here some of the inductive codes were moved to the PCK-based codes, and also, I merged some codes with few quotes into more prominent codes. Some of the inductive codes were integrated into more prominent categories. A few of the inductive codes were eliminated due to the low number of quotes and because they were not able to be integrated into other codes.
Post-coding and pre-writing phase	I organized the codes and cases in a matrix to be able to visualize the data better and start answering the research questions. The matrix allowed me to identify what are the most salient topics or dimensions considered by the participants. Also, by ***cross-case item analysis,*** I was able to identify which of these topics or dimensions were mentioned by all or most of the participants, to identify what are some common topics considered by the PSTEs in the three cases (RQ1). Also, by comparing the different cases, I was able to see the range and diversity of challenges they faced, so I could organize them and describe them (RQ2).

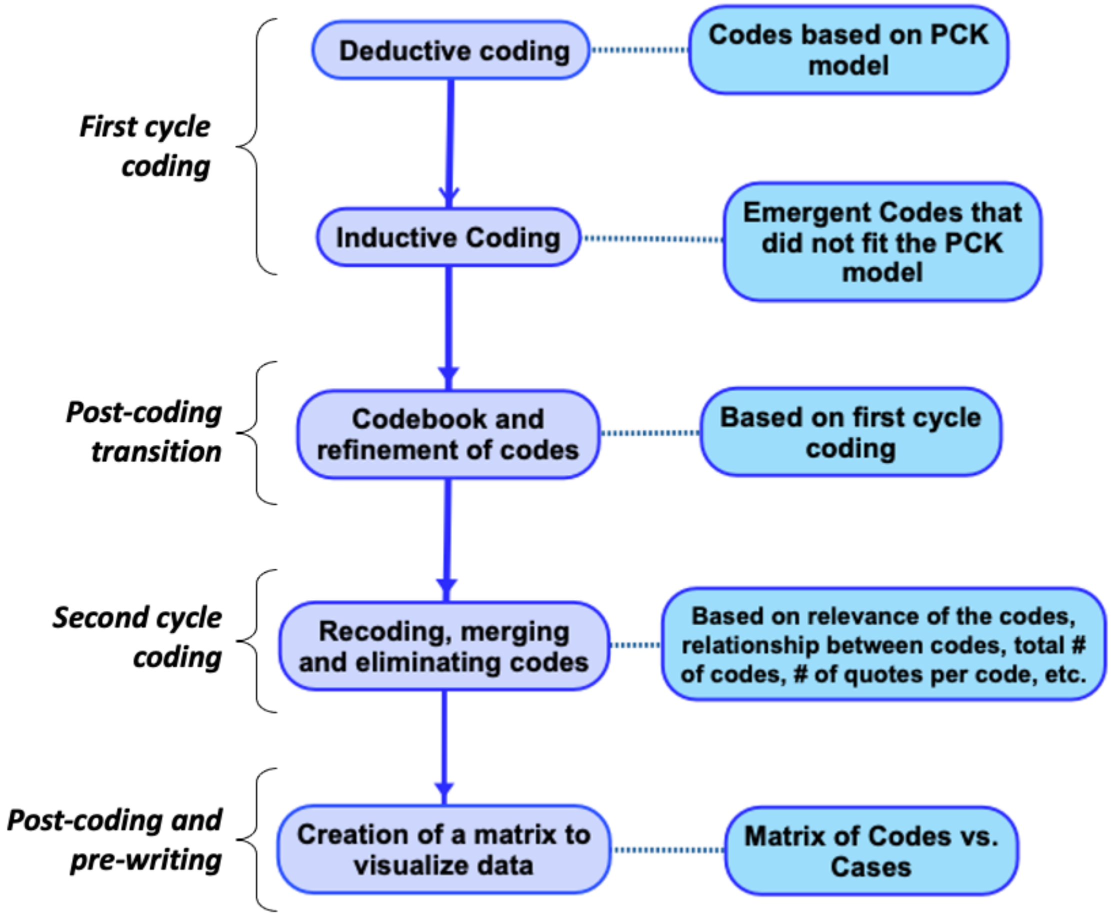

Figure 6. Summary of steps for the analytical process.

Assessing data quality and trustworthiness

Credibility (internal validity) is addressed through two approaches: triangulation of qualitative sources and member checking (Patton, 2015). For *triangulation of data sources*, I checked consistency through the different participant-generated artifacts and interviews. Themes were developed based on the different data sources, which facilitated the process of checking for consistency across them. For instance, to create the themes for the challenges faced by PSTEs when designing their SMCs and the factors influencing their PDM, data from the interviews (think aloud and final interviews), and the oral and written reflection were used to create the themes. All these data sources were put into NVivo, and I selected quotes from all of them to develop the themes, so each theme contained quotes from multiple sources. For *member checking*, I presented preliminary findings to participants during the final interview and asked them to assess the accuracy of these findings and suggest modifications if necessary.

CHAPTER 4

4. FINDINGS

The overall purpose of this research was to characterize the design or planning process of SMCs by prospective STEs. To achieve this, I identified the topics that PSTEs considered in their SMC, the challenges they encounter when designing their SMC, and factors that influenced their pedagogical decision-making process when designing their syllabi. Participants were organized in three cases according to the SMC they designed: elementary, middle school, and secondary cases. This chapter presents the qualitative results for the three research questions addressed in this study. These findings are presented here in three main sections that align with the three research questions: the dimensions/topics considered by PSTEs, the challenges faced by PSTEs when designing a SMC, and the factors influencing PSTEs' pedagogical decision-making. Each of these three main sections starts with a cross-case analysis, where similarities and differences were identified across the three cases. The specific findings for each case are also presented in each of the main sections.

Dimensions/topics considered by prospective science teacher educators when designing a science method course

Cross case analysis of topics considered in the SMC syllabi

Similarities

If we look at the aggregated results for the three cases, participants included contents that covered all the dimensions considered in the pentagon PCK model (Park & Oliver, 2008a). There is an implicit alignment between the topics covered in these syllabi and the dimensions of the PCK framework, since none of them explicitly used PCK as a guiding framework. More specifically, the common PCK dimensions covered across all three cases were OTS, KISR, KSC, and KSU.

Nearly all the participants (except for one participant in the middle school case) considered the analysis, discussion, or interpretation of science curricular documents (either national, state, or county standards) as part of the contents and activities for their SMCs. PSTEs thought that it was important for student teachers to be familiar with the standards since they will have to design teaching experiences based on these documents. They also argued that curricular documents contained all the knowledge that is expected for a teacher to know, so they consider it important to expose student teachers to these documents. Additionally, standards documents were also one of the main factors influencing their pedagogical decision-making process when designing SMCs in the three cases.

At the same time, there seems to be a lack of emphasis on the KAs dimension. This is because KAs topics were considered by fewer participants (2 elementary PSTEs, 1 middle school PSTE, 0 secondary PSTE), and most of them did not include explicit references to specific assessment strategies or instruments for science. This is evident in the top rings with the aggregated cases in **Figure *7***. This could be explained by the fact that most of the participants haven not taken assessment courses specifically for science in graduate school by the time data was collected for this study. This is also aligned with what has been found in the literature. Jablon (2002) reviewed the areas that are being studied through coursework in 64 science education doctoral programs. He found that only 11 of the 64 reviewed doctoral programs required a whole course on assessment in science education. Also, many times, it is expected that student teachers could learn about assessment in other courses in their teacher preparation programs, so instructors may have this in mind when designing SMC syllabi, and they may choose not to include many science assessment-related contents in favor of other science pedagogy areas.

From the professional knowledge bases, participants in the three cases explicitly addressed PK, CK, and AK, but none of them considered CuK in their syllabi. This is expected since science teacher preparation programs generally include courses on curriculum where student teachers learn about CuK. Also, only participants in the elementary case considered KS, which refers to ideas about student cognitive and physical development, understanding student differences, among others.

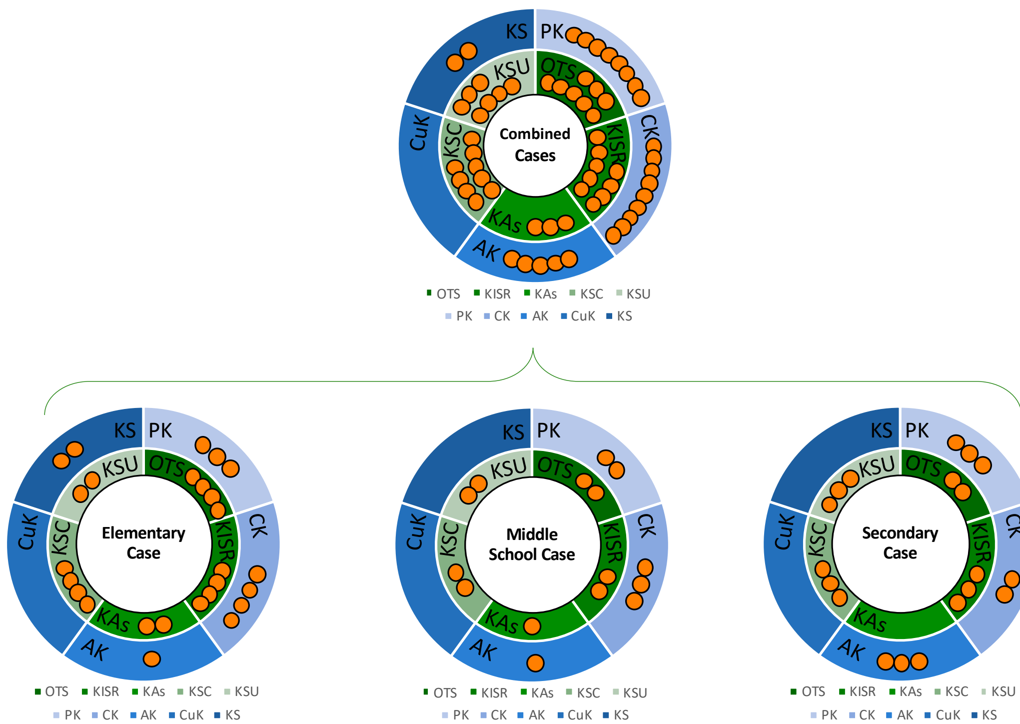

Figure 7. PCK and professional knowledge bases dimensions covered in the Elementary, Middle School, and Secondary Science Methods Course syllabi.
(Dots in the dimensions of the outer and inner rings represent the dimensions considered by each participant in their SMC syllabi. *OTS: Orientation to teaching science; KISR: Knowledge of instructional strategies and representations for teaching science; KAs: Knowledge of assessment of science learning; KSC: Knowledge of science curriculum; KSU: Knowledge of students' understanding in science; CK: Content Knowledge; PK: Pedagogical knowledge; KS: Knowledge of students; CuK: Curricular knowledge; AK: Assessment knowledge*).

Differences

There are no significant differences between the three cases in terms of the PCK dimensions they considered in their SMC syllabi. This may be explained by the similar background of the participants. Almost all of them (nine out of 10) have had experiences as science teachers, they are all doctoral students in science education or science curriculum and instruction, all of them have a science content background and have had experiences with teachers.

A difference is that it was more common for participants from the elementary and middle-school cases to include science content knowledge (100% of participants) compared with participants from the secondary case (66% of participants). Even one of the participants in the middle school level included only science contents in his/her syllabus. This can be explained by the fact that many times in elementary and middle school teacher preparation programs, instructors of SMC need to cover science content knowledge, in addition to science pedagogy contents (Santau et al., 2014). This is because this particular group of student teachers may not have taken enough credit hours of science content courses during their preparation (Allen, 2003; Palmer, 2002), or they may not feel qualified or prepared to teach science after graduating from teacher preparation programs (Weiss et al., 2001), so instructors need to address these gaps in the SMCs.

Another difference was that, despite all participants considered curricular documents as part of their syllabus during the design process, local participants (US) considered national and local standards, while the international participants considered mostly national standards. This is expected, since local participants have K-12 teaching experience in the US, so they are familiar with local standards as well, in contrast with international participants who do not have K-12 teaching experience in the US. Additionally, in some cases, their countries have national standards only.

Elementary Science Methods Case

PSTEs designing elementary science methods courses (ESMC) explicitly included all the PCK dimensions as a group (elementary case) in their syllabi. **Figure *8*** represent the PCK and professional knowledge bases dimensions covered in the ESMC syllabi designed by each of the four PSTEs and the aggregated codes. Among the most salient topics considered by PSTEs for each *PCK dimension* are research-based teaching and constructivism (OTS); instructional strategies, scientific inquiry, and lab safety (KISR); design of instruments to identify alternative conceptions (KAs); curricular documents discussion (local, national), integration of science across the curriculum, and instructional / professional resources compilation (KSC); students' understandings / misconceptions of science (KSU). **Table *7*** includes some examples of these and other topics included in the ESMC syllabi for each PCK dimension. Some of the PSTEs didn't include topics related to KAs and KSU.

Among the most salient topics considered by PSTEs for some of the *professional knowledge bases* dimension in their syllabi are lesson planning, culturally relevant / responsive science teaching and science for all, differentiated instruction for diverse range of learners (gifted, ESE and ELL), and classroom management (PK); nature of science and scientific knowledge, socio-scientific issues, integration of science with other content areas (CK); and formative and summative assessment (AK). **Table *8*** includes some examples of these and other topics included in the ESMC syllabi for each professional knowledge bases dimension. Some salient topics that didn't fall under in any of the PCK or professional knowledge bases dimensions (emergent codes) are reflection, a teaching component (microteaching, teaching demos), learning contexts, use of technology, diversity and equity issues (culturally responsive teaching, social justice in science), and effectiveness in teaching science (see **Table *9***).

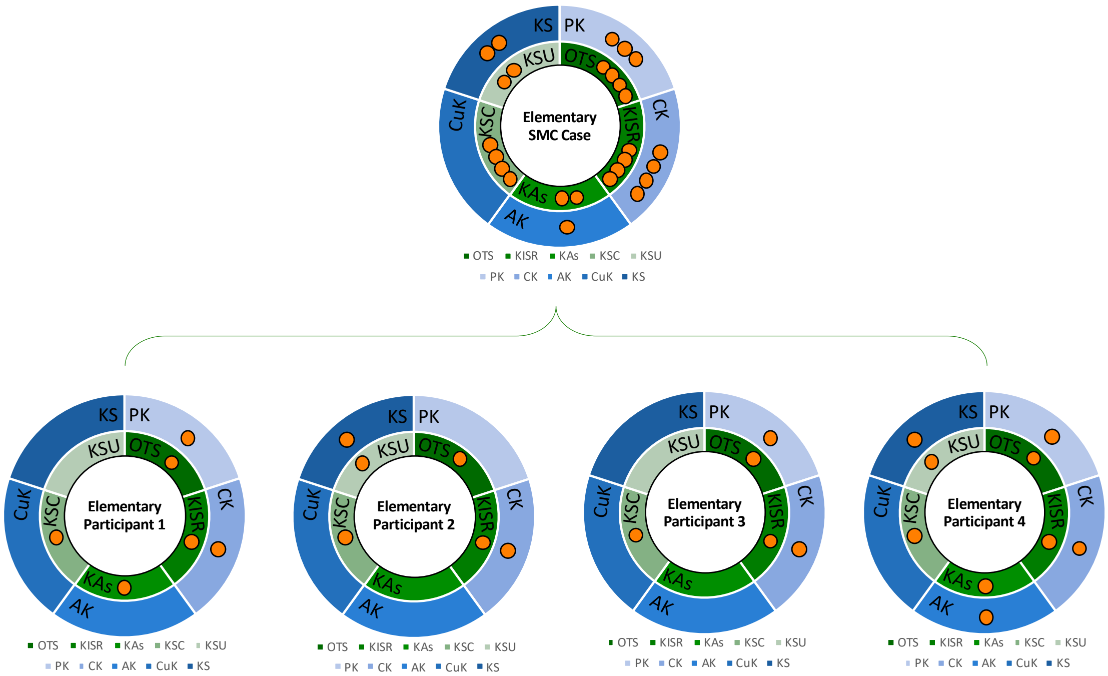

Figure 8. PCK and professional knowledge bases dimensions covered (indicated by the dots) in the Elementary Science Methods Course syllabi designed by each of the four PSTEs (bottom). The aggregated codes for each dimension are represented at the top diagram.

(Dots in the dimensions of the outer and inner rings represent the dimensions considered by each participant in their SMC syllabi. *OTS: Orientation to teaching science; KISR: Knowledge of instructional strategies and representations for teaching science; KAs: Knowledge of assessment of science learning; KSC: Knowledge of science curriculum; KSU: Knowledge of students' understanding in science; CK: Content Knowledge; PK: Pedagogical knowledge; KS: Knowledge of students; CuK: Curricular knowledge; AK: Assessment knowledge*)

Middle School Science Methods Case

PSTEs designing middle school science methods courses (MSMC) explicitly included all of the PCK dimensions as a group (middle school case) in their syllabi. **Figure *9*** represents the PCK and professional knowledge bases dimensions covered in the MSMC syllabi designed by each of the four PSTEs and the aggregated codes. Among the most salient topics considered by PSTEs for each *PCK dimension* are: constructivism and conceptual change (OTS); instructional strategies; modeling; classroom safety (KISR); performance assessment tasks and rubrics for evaluating scientific inquiry (KAs); curricular documents discussion (local, national), and sequencing science contents (KSC); and students' understandings / misconceptions of science (KSU). **Table *7*** includes some examples of these and other topics included in the MSMC syllabi for each PCK dimension. Two of the PSTEs didn't include topics related to KAs and one of them didn't include any PCK related topic.

Among the most salient topics considered by PSTEs for some of the *professional knowledge bases* dimension in their syllabi are lesson planning, differentiated instruction for diverse range of learners, and classroom management (PK); nature of science, socio-scientific issues (CK); and formative and summative assessment (AK). **Table *8*** includes some examples of these and other topics included in the MSMC syllabi for each professional knowledge bases dimension. Some salient topics that didn't fall under in any of the PCK or professional knowledge bases dimensions (emergent codes) are reflection, learning contexts, and diversity and equity issues (ethical, cultural and social issues in science teaching) (see **Table *9***).

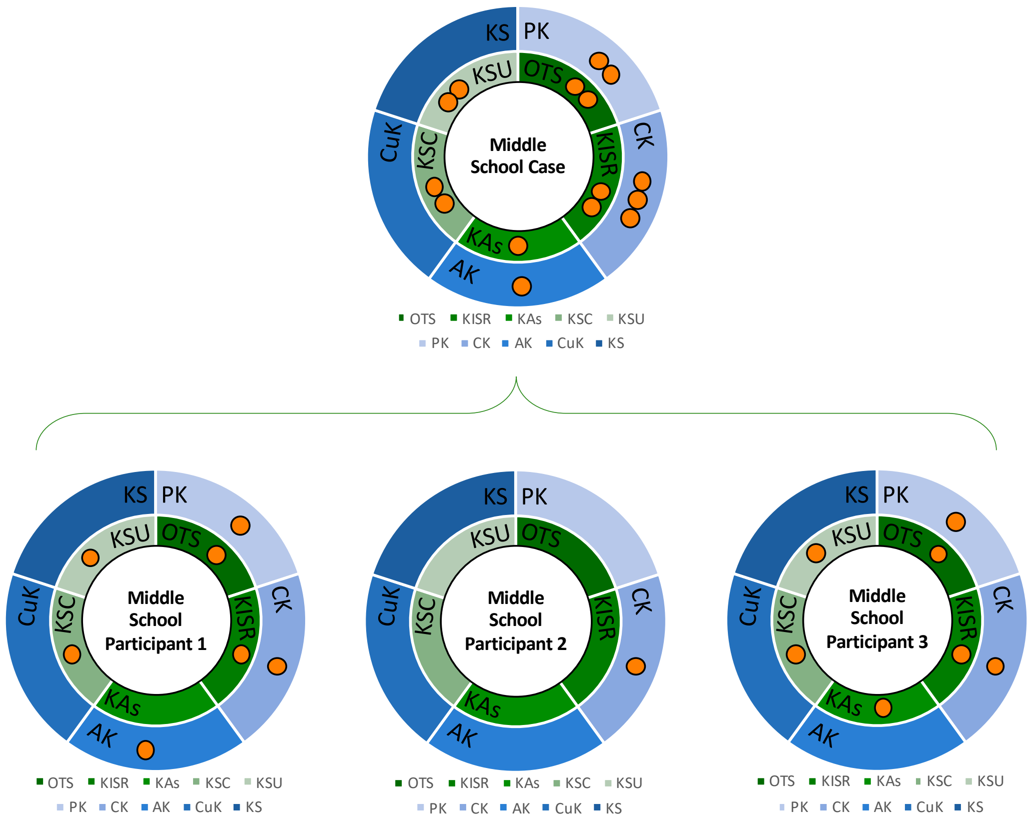

Figure 9. PCK and professional knowledge bases dimensions covered (indicated by the dots) in the Middle School Science Methods Course syllabi designed by each of the three PSTEs (bottom). The aggregated codes for each dimension are represented on the top diagram.
(Dots in the dimensions of the outer and inner rings represent the dimensions considered by each participant in their SMC syllabi. *OTS: Orientation to teaching science; KISR: Knowledge of instructional strategies and representations for teaching science; KAs: Knowledge of assessment of science learning; KSC: Knowledge of science curriculum; KSU: Knowledge of students' understanding in science; CK: Content Knowledge; PK: Pedagogical knowledge; KS: Knowledge of students; CuK: Curricular knowledge; AK: Assessment knowledge*)

Secondary Science Methods Case

PSTEs designing secondary science methods courses (SSMC) explicitly included most of the PCK dimensions as a group (secondary case) in their syllabi, except for KAs. **Figure *10*** represent the PCK and professional knowledge bases dimensions covered in the SSMC syllabi designed by each of the four PSTEs and the aggregated codes. Among the most salient topics considered by PSTEs for each *PCK dimension* are research-based teaching, active learning (OTS); instructional strategies, and scientific inquiry (KISR); curricular documents discussion (national), and instructional / professional resources compilation (KSC); and students' understandings / misconceptions of science (KSU). **Table *7*** includes some examples of these and other topics included in the SSMC syllabi for each PCK dimension. The three PSTEs didn't include topics related to KAs, and one of them didn't include topics related to OTS.

Among the most salient topics considered by PSTEs for some of the *professional knowledge bases* dimension in their syllabi are lesson planning, culturally relevant / responsive science teaching and science for all, differentiated instruction for diverse range of learners (special needs), classroom management (PK); nature of science and scientific knowledge; integration of science with other content areas (CK); and types of assessments (AK). **Table *8*** includes some examples of these and other topics included in the SSMC syllabi for each professional knowledge bases dimension. Some salient topics that did not fall under in any of the PCK or professional knowledge bases dimensions (emergent codes) are reflection, a teaching component (microteaching, teaching demos), and learning contexts. For more details see **Table *9***.

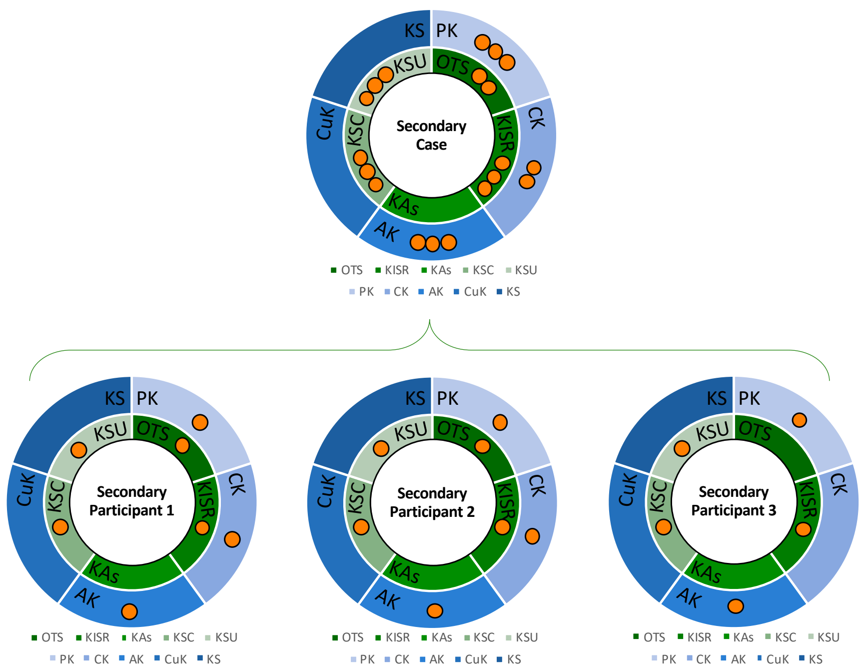

Figure 10. PCK and professional knowledge bases dimensions covered (indicated by the dots) in the Secondary Science Methods Course syllabi designed by each of the three PSTEs (bottom). The aggregated codes for each dimension are represented on the top diagram.

(Dots in the dimensions of the outer and inner rings represent the dimensions considered by each participant in their SMC syllabi. *OTS: Orientation to teaching science; KISR: Knowledge of instructional strategies and representations for teaching science; KAs: Knowledge of assessment of science learning; KSC: Knowledge of science curriculum; KSU: Knowledge of students' understanding in science; CK: Content Knowledge; PK: Pedagogical knowledge; KS: Knowledge of students; CuK: Curricular knowledge; AK: Assessment knowledge*)

Table 7. Examples of topics included in the elementary, middle school, and secondary science methods courses for each PCK dimension (topics common to at least two of the three cases are in bold, the numbers in parenthesis indicate the number of participants in each case that considered these topics).

	Elementary Science Methods Syllabus (4)	*Middle School Science Methods Syllabus (3)*	*Secondary Science Methods Syllabus (3)*
OTS	**Research-based teaching** (2), activity-centered; project-centered classroom; learning theories; **constructivism** (2); cognitive, social, and cultural perspectives	Reform-based science education, **constructivism**; conceptual change	**Research-based teaching**; theories of science education; inquiry-based and phenomena-based science teaching; active learning
KISR	**Instructional strategies** (3) (Lectures, discussions, demos); **scientific inquiry** (3); hands-on activities; labs and laboratory **safety** (2) (disposal; living organisms); **modeling**	**Instructional strategies** (investigation with data, data representation/ graphing, ambitious science teaching); hands-on; direct Instruction; analysis of a big variety of science teaching activities; **modeling** subject-specific strategies (in earth and space science, physics); creativity and problem solving when designing teaching activities; science classroom **safety**	**Instructional strategies** (based on learning needs, type of content, teaching approaches, advantages / disadvantages); **scientific inquiry** (2); laboratory activities; physics teaching strategies (teaching experiments)
KAs	Design of instruments to identify alternative conceptions in science	Traditional assessment items (multiple choice and constructed response); performance assessment tasks and rubrics for evaluating scientific inquiry (2) and engineering investigation; eliciting student prior knowledge (electricity)	---
KSC	**Curricular documents** analysis / interpretation / discussion (NGSS, GPS, Florida standards) (4); integration of science across the curriculum (2); **instructional / professional resources compilation** (2); curricular materials appropriate for early childhood science	**Curricular documents** analysis / interpretation / discussion (NGSS, GSE, County standards) (2); defining the scope and sequence of science contents of a curriculum; select, adapt, and construct activities lessons, units, and projects	**Curricular documents** analysis / interpretation / discussion (NGSS, Benchmarks for science literacy, national & state science education standards) (3); i**nstructional / professional resources** compilation (2); design demonstrative instruments for teaching science (physics); content course design (physics, physics lab)
KSU	**Students' understandings / misconceptions of science** (2); **background knowledge** and experiences of students	**Students' understandings / misconceptions of science** (photosynthesis, physical science) (2)	**Students' understandings / misconceptions of science** (2); **background knowledge**

Table 8. Examples of topics included in elementary, middle school, and secondary science methods courses for each professional knowledge bases dimension (topics common to at least two of the three cases are in bold, the numbers in parenthesis indicate the number of participants in each case that considered these topics).
(*ESE: exceptional student education, ELL: English Language Learners)*

	Elementary Science Methods Syllabus (4)	***Middle School Science Methods Syllabus (3)***	***Secondary Science Methods Syllabus (3)***
PK	**Lesson planning** (3); **culturally relevant / responsive science teaching and science for all** (3); **differentiated instruction** for diverse range of learners (gifted, ESE and ELL) (2); **classroom management**	**Lesson planning** (for earth science, and life science) **differentiated instruction** for a diverse range of learners; **classroom management** (2)	**Lesson planning** (3); **culturally relevant / responsive science teaching and science for all**; **differentiated instruction** for diverse range of learners (special needs); **classroom management**;
CK	**Nature of science** and scientific knowledge / inquiry (2); **socio-scientific issues** (2); science processes skills; historical and socio-cultural construction of science knowledge; relationship between science, technology, and society (STS); crosscutting concepts; earth & space science (2); life science (2); physical science (2); engineering & technology (2); citizen science; sustainability; subject matter in standards**;** **integration of science with other content areas** (2); integration of STEM content and practices	**Nature of science**; **socio-scientific issues** and controversial topics (pandemics, vaccines, fires, water, climate change, GMOs, robots, renewable energy, cancer research, organ donation, nanotechnology, nutrition, and diet research); scientific literacy; photosynthesis; Newton's laws of motion; graph literacy; thermal energy concepts infused with mathematics; engineering design; scientific research proposal	**Nature of science and scientific knowledge** (2); **integration of science with other content areas**; scientific thinking and reasoning; role of science in everyday life, science and engineering practices
AK	**Formative & summative assessment**, diagnostic assessment, achievement vs. growth	**Formative & summative assessment**; differentiated assessment	Types of assessments (2); performance assessment, basic principles for designing an exam; develop assessment items
CuK	---	---	---
KS	Piaget's stages of cognitive development (physical, mental, and emotional aspects); students' cognitive abilities.	---	---

Table 9. Examples of other topics included in elementary, middle school, and secondary science methods courses (emerging codes, the numbers in parenthesis indicate the number of participants in each case that considered these topics).

Elementary Science Methods Syllabus (4)	**Middle School Science Methods Syllabus (3)**	**Secondary Science Methods Syllabus (3)**
Reflection (4)	Reflection (2)	Reflection (2)
Teaching component (2) (Microteaching, teaching demos)	Teaching component (1) (Microteaching, teaching demos)	Teaching component (2) (Microteaching, teaching demos)
Learning contexts (2)	Learning contexts (2)	Learning contexts (2)
Use of technology (2)	Use of technology (1)	Use of technology (1)
Diversity and Equity issues (3) (Culturally responsive teaching, social justice in science)	Diversity and Equity issues (2) (Ethical, cultural and social issues in science teaching)	Diversity and Equity issues (1) (equality-equity issues related to science)
Classroom observations (1)	Classroom observations (1)	---
Effectiveness in teaching science (2) (Teachers' effectiveness, effective science instruction)	---	---
Others (1) (Teachers' identity, sustainability, and environmental ed., interdisciplinary teaching)	Others (1) (Out of field instruction, informal education, science fair)	Others (1) (Self-regulated learning)

Challenges faced by prospective science teacher educators when designing a science method course

Cross case analysis of challenges faced by PSTEs

Similarities

Participants from the three cases presented four common challenges (general themes), out of five themes identified. These are lack of experience-related challenges, content-related challenges, resources-related challenges, and assessment-related challenges. Based on the subthemes (or subcodes), two common challenges for the three cases were “selecting and sequencing the topics” and “the lack of an organizational framework or national standards for science teachers”. Some of them argued that it was challenging for them not to have a defined curriculum for this class. All of them have had experiences teaching K-12, where they had a curriculum defining the content they had to teach. They are familiar with the design of lessons and instructional resources based on curricular documents with defined teaching units, but it was challenging for them to select and sequence the contents for a course without having a defined curriculum for their SMC syllabi. Moreover, only one PSTE in the secondary case mentioned that s/he was not familiar with the content relevant for science teachers in the context of a SMC, which could be explained by the fact that s/he was in the second year of his/her doctoral program. This suggests that most of the participants seem to be familiar with the content that are relevant for science teachers in the context of a SMC, but they just struggled with selecting and sequencing these contents.

Additionally, the fact that the participants of this study did not have a clear idea of the overall structure and curriculum of the science teacher preparation program in which they would implement their SMCs also contributed to making challenging for them to make the selection of topics.

This challenge is aligned with the diversity of approaches and topics implemented in SMCs presented in the literature review. The contents and the goals of these courses can go in multiple directions to serve the specific needs of a group of student teachers in a particular teacher preparation program. This diversity in SMCs could have contributed to making challenging for participants to select and sequence topics for their course. Regarding the lack of national teacher preparation standards mentioned by participants, participants mentioned that this could have helped them to organize the structure or topics in their SMCs. In this sense, the "*2020 NSTA/ASTE Standards for Science Teacher Preparation*" (Morrell et al., 2020) provide a series of areas in which student teachers should be prepared, like content knowledge, content pedagogy, professional knowledge, and skills, among others. These are recommendations for the overall organization of science teacher preparation programs. Although these standards do not provide specific guidelines for the design of SMCs, STEs could have benefited from being familiar with this document because many of the standards or areas included can be addressed in the context of SMCs.

Another common challenge (subtheme) between the elementary and secondary cases was "designing assessments/rubrics" for this class. They expressed issues related to the design of assignments, issues defining the number and format of assignments, and time management issues when planning the assignments for this class, for instance, deciding how much time to devote to each activity. Despite they have all been exposed to different assessment strategies during their undergrad programs and graduate school, they do not feel familiar enough with specific assessment strategies for SMCs. These may be related to another common challenge identified in the elementary and secondary case, which is the “lack of experience teaching a SMC”. Only one out of four participants in the elementary case, and one out of three participants in the secondary case have been TAs for a SMC. This could be contributing to their lack of confidence in designing assessments for this class. Another explanation for this challenge related to the research design of the study is the fact they were designing a SMC for a hypothetical situation in the future, so there were some contextual aspects relevant for their course design that they could not anticipate. Some of them, for instance, mentioned that not knowing the total number of sessions they will have, or the total number of students made challenging for them to plan some type of assessment activities, like micro-teaching or presentations.

Other common challenges (subthemes) to the elementary and secondary cases were “the lack of experience teaching a SMC” and “finding and selecting teacher-appropriate resources” for this class. Another similarity between the elementary and secondary cases is that participants in these groups presented the same challenges for the general themes identified for this research question.

Differences

One difference is that participants in the middle-school case presented fewer challenges than the elementary and secondary cases. There were fewer themes identified for this case. Specifically, they did not present "lack of experience" or "defining goals and expectations" related challenges. This may be explained by the fact that all participants in the middle-school case were more advanced in their doctoral programs (2 of them in their last year), and also two of the participants in this case had previous experience designing and teaching SMC. Besides this, the rest of the general themes identified for the challenges faced by PSTEs were the same in the three cases.

Figure *11* summarizes these similarities and differences in the challenges faced during the course design process across cases.

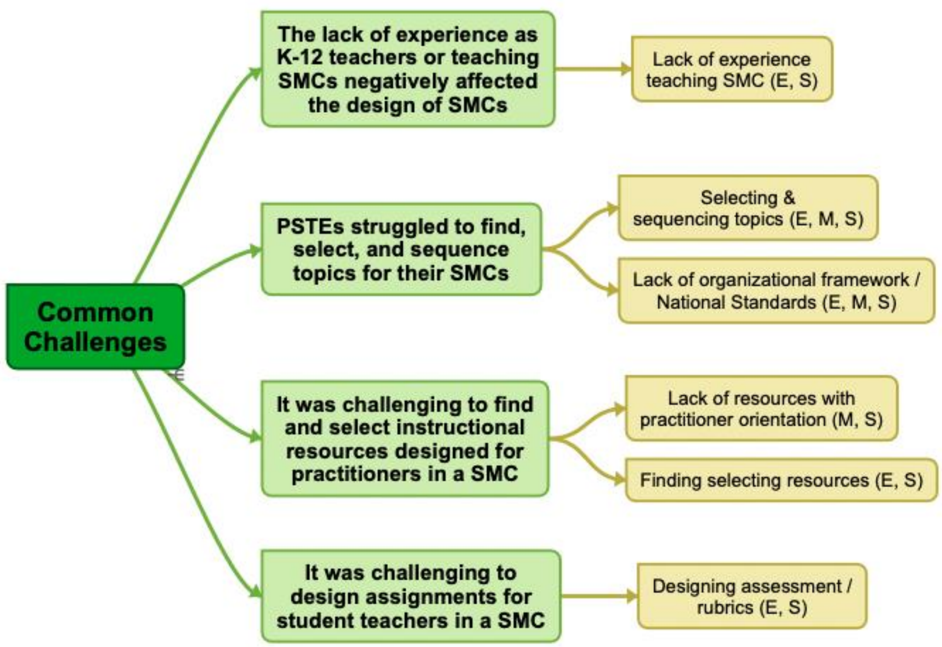

Figure 11. Thematic network showing the common challenges presented by PSTEs in the elementary, middle school, and/or secondary cases during the design of their SMC syllabi.
(*E: Elementary case, M: Middle-school case, S: Secondary case*)

Elementary Science Methods Case

In the following sections I discuss the identified challenges that PSTEs' presented during the process of designing their elementary science methods courses (ESMC). The thematic network presented in **Figure *12*** summarizes these challenges.

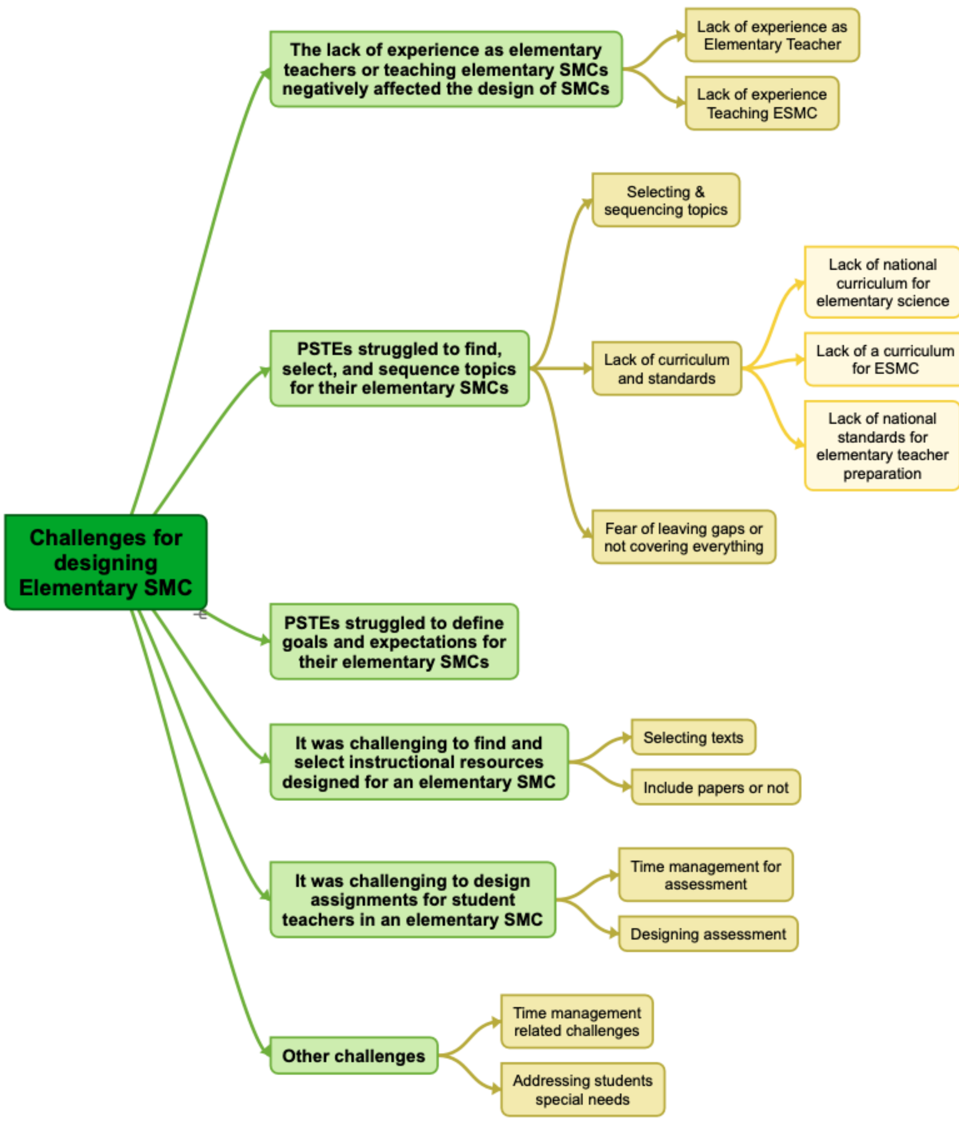

Figure 12. Thematic network summarizing the identified challenges presented by PSTEs during the design of ESMC syllabus (*ESMC: elementary science methods course*).

- **The lack of experience as elementary teachers or teaching elementary SMCs negatively affected the design of SMCs**: Lack of experience was one of the main challenges faced by most of the PSTEs designing ESMC. One of these challenges was the lack of experience as elementary teacher or teaching elementary science. They mentioned that this causes them a lack of confidence in deciding the goals of the course and, in general, they did not feel prepared for this task. PSTEs also mentioned the lack of experience teaching ESMC. They argue that having this experience would have provided a framework for them to select and sequence contents.

Selected quotes
"I think if I also had been an elementary school teacher had a bit more confidence in exactly how it would turn out, or a better idea of how it would turn out. I would probably go from like straight up my own goals as the route, instead of someone else's content, it's the route. Like that's something that I want to be able to do one day. But I don't feel prepared to do or kind of comfortable doing yet."
"Because I never taught in elementary, first of all, I and... I was not an elementary school science teacher. So basically, I don't know how to teach such a class."
"I don't have this experience in elementary School, and I kind of, I think I kind of lack of many things, lack of many things that is like, required in the elementary school science class."
"I've never had an opportunity to teach or co-teach (including as a TA) a science methods course. So I didn't have a frame of reference for the content of a methods course in terms of WHAT content to include and HOW to sequence the content so that it could be meaningful for my students."

- **PSTEs struggled to find, select, and sequence topics for their elementary SMCs**: PSTEs also mentioned challenges related to the contents of the ESMC. For instance, they mentioned they had difficulties selecting and sequencing the contents of the syllabus. Some of them mentioned the lack of an organizational framework or curriculum for this course as a factor for this challenge, the lack of a national curriculum for elementary science, and the lack of national standards for elementary teacher preparation. One of them also mentioned the fear of leaving gaps and not covering all the contents that are important for novice elementary teachers.

Selected quotes
"The most challenging part for me it was figuring out the sequencing"
"the kind of things that I got out of this was like figuring out teaching a methods course where the methods is the content. Because I can sequence biology. I know which order works well. Yeah, but trying to figure out how I wanted to sequence methods content, yeah, which is entirely different."
"The scope and sequence of the course are what took me the longest to complete"
"Some of that... also comes from this whole idea of academic freedom. This is the first time I've ever been given academic freedom, which sounds liberating, right?, but that actually means it's kind of scary, because I've always had a list of standards that says you must do XYZ in order to complete and be a good... teacher, and then we're gonna evaluate your students to make sure that they've learned X Y and Z. And I don't have that now."
"I don't know here, but... at [my country] you will have like a national curriculum. So, for the high school teacher, they are building their class, they can actually look at the National Curriculum and they will have a very clear concrete expectation for each class, so it's easier for teacher... because there was... a National Guideline, so high school life. But teaching in colleges... like a university class, they don't really have like a nation of curriculum"
" In addition, there is no national standard for the science method course for elementary teachers' education that I can base it on."

"But do we have a standard for different college or different teacher education program? say, if you are a [University] and our teacher education program class will have those things, but those are actually... very depend on who taught this class."
"If you got your certificate in other teacher college... you probably will get a different view, you will have a different class, a different material from that to college, so it's not like a whole country unit... some teacher, they graduate, and they got a certificate, it has maybe... higher expectation than other from other teachers college. So the quality of a teacher is varies because they don't have like a national standard for education program."
"I think the most difficult part for me is just the worry. It's every teachers worry, the worry that I'm going to leave major gaps, that... I won't, you know, do a good enough job of explaining"

- **It was challenging to find and select instructional resources designed for an elementary SMC**: PSTEs also had some challenges for finding resources to teach an ESMC. For example, some of them struggled to decide on what was the best textbook for this class, due to the great diversity of textbooks on elementary science methods. Others also struggled to decide if the readings from a textbook were enough, or if it was also a good idea to include some professional journal papers too.

Selected quotes
"There are so many materials you can use, and which is appropriate, which is a best for your students. I just need to need to decide"
"I was trying to figure out, do I stop at a textbook or do I include like primary literature or teacher, literature, like from professional journals and professional organizations."
"Also, texts seem to be an issue for me. This is one reason why this reflection, talking with you, and gathering resources were helpful for me."

- **PSTEs struggled to define goals and expectations for their elementary SMCs**: Setting goals and expectations was another challenge for designing ESMC. One of the PSTEs argued that it would be very challenging for him/her to set goals and expectations for this class if s/he didn't have a syllabus to look for goals and expectations.

Selected quotes
"I agree with all of them [objectives] but I was thinking if you are going to start from on zero, it's really hard... Of course I agree with the course objective... "the future teacher is going to have positive attitude towards science and science teaching and learning", of course, that is an objective I agree, but if I just needed to start on zero, I don't know where I should start"

- **It was challenging to design assignments for student teachers in an elementary SMC**: PSTEs also presented challenges related to the assessment or assignments in their ESMC. For instance, one participant expressed time management issues when planning the assignments for this class, more specifically, deciding how much time to devote to each activity. Another participant struggled to design assessments for his/her ESMC.

Selected quotes
"I think it is [challenging] to imagine... how much time they need for each assignment in each course, because I never taught this before. It is just like when you first prepare the class is... time management is one part that is very hard to control or decide if you don't have experience... Just I don't know... how much time you should say, for each activity or each assignment."
"I was thinking about one student to do teaching demo. But I don't know if that is going to happen in one week or two weeks, so I was expecting that probably, they will teach 15 minutes, but also depends on how many students were there"
"creating the assessments for learning of the material were the most difficult. I just find that part difficult because I tend to second-guess myself as to the best way to show their learning, even using research. I also tend to “forget” to tie it back to that assessment. I think it is explicit, but the students do not."

- **Other challenges**: Other challenges mentioned by PSTEs has to do with time management issues, for instance, including resources and activities without knowing how much time they require to be implemented, or defining the number of hours of work in class vs. outside the class. They also mentioned challenges for addressing students' special needs.

Selected quotes
"If you really have some student they have like health or a mental issue in my challenge. If you, I never just like just like my classmates. I never have any classmates like blind or have like another like physical or mental problem ..., but if you do have a student that need special help, then there might be challenge."

Middle School Science Methods Case

In the following sections, I discuss the identified challenges that PSTEs presented during the process of designing their middle school science methods courses (MSMC). The thematic network presented in **Figure *13*** summarizes these challenges.

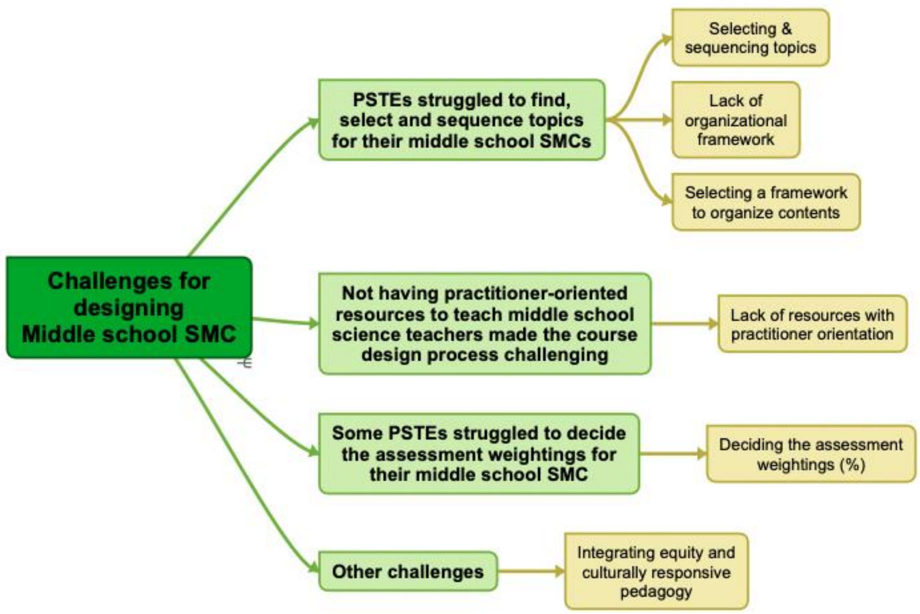

Figure 13. Thematic network summarizing the identified challenges presented by PSTEs during the design of MSMC syllabus (*MSMC: middle school science methods course*).

- **PSTEs struggled to find, select and sequence topics for their middle school SMCs**: PSTEs also presented challenges related to the contents for their MSMC. For instance, they had difficulties selecting and sequencing the contents for this course. The main reason they identified was the lack of a clear organizational framework or curriculum for this course. In their experiences teaching K-12, they had a curriculum defining the content they had to teach, so it was challenging for them to design a course without having a defined curriculum for the MSMC. One of them used two educational theories as a framework for the design of his/her MSMC, but s/he expressed difficulties to decide on what framework is appropriate for a science methods course.

Selected quotes
"The most difficult parts were to decide which topic should include"
"One part is deciding to subject each week,... what topic are good for this class"
"It's weird in college because you don't have like... standards like, there isn't a set of thing that you have to do. So it gets a little like, I was uncomfortable that I would be like doing a disservice."
"I do think not having... a curriculum. Like when I was teaching k-12, it was like you had a document that had the five standards you're supposed to teach in that unit, how long that unit was supposed to be, and then, like, basically an example of like the assessment question they would have. So, what was weird about this class is that didn't exist. And realistically, the goals are pretty broad. Because I would always ask, like, what are the things that I have to do? Like, where's my backbone? And then I'll sprinkle things in but like, what are the things that are required?"
"It was difficult to have no real outline. Coming from the classroom, I was used to having at least a minimal outline of required standards. Then I would fill in my own strategies and activities. Here I only had a brief course description. I was afraid of doing the wrong thing and didn't really know where to go to make sure I was doing it right."
"one of the major difficulties that I faced was to decide what was the theoretical framing that I would use. It was my starting point, and it took me quite a while to decide on the theoretical framework. I went back and forth between many theories. I saw that PCK was a framework which is very widely used, both at the secondary as well as the elementary level. However, I did not want to use that framework and I wanted to use something more contemporary. This was a decision which was kind of a major decision for me to make. I then finally decided to use the theoretical framing of the constructivist approach to teaching and Mark Windschitl's ambitious science teaching"

- **Not having practitioner-oriented resources to teach middle school science teachers made the course design process challenging**: One of the participants expressed concerns about finding teaching resources for this class. S/he mentioned that s/he didn't have practitioner-oriented resources for this course.

Selected quotes
"I wish I had more teacher-appropriate articles on student learning."

- **Some PSTEs struggled to decide the assessment weightings for their middle school SMC**: One of the participants expressed challenges related to the assessment of this course. S/he mentioned that s/he had difficulties deciding how to weight different assignments s/he designed for this course.

Selected quotes
"And the second challenge is deciding to grading. How activities... should get which points, for example... to midterm exam, final exam, weekly reflection paper, how can I divide to their percentages? So, it's a little bit hard for me."

- **Other challenges**: Other challenges mentioned by one of the PSTEs were the integration of equity and culturally responsive frameworks. The difficulties had to do with integrating these frameworks with the frameworks that s/he was already using to design the MSMC.

Selected quotes
"One major weakness of the course was that I felt that I did not integrate equity very well in the course. Initially, I did think of using an equity-based theoretical framework, I thought of using culturally responsive pedagogy for designing the framework, but then I was not really sure if I could combine culturally responsive teaching and OOF [out of field teaching] in the framework"

Secondary Science Methods Case

In the following sections I discuss the identified challenges that PSTEs presented during the process of designing their secondary science methods courses (SSMC). The thematic network presented in **Figure *14*** summarizes these challenges.

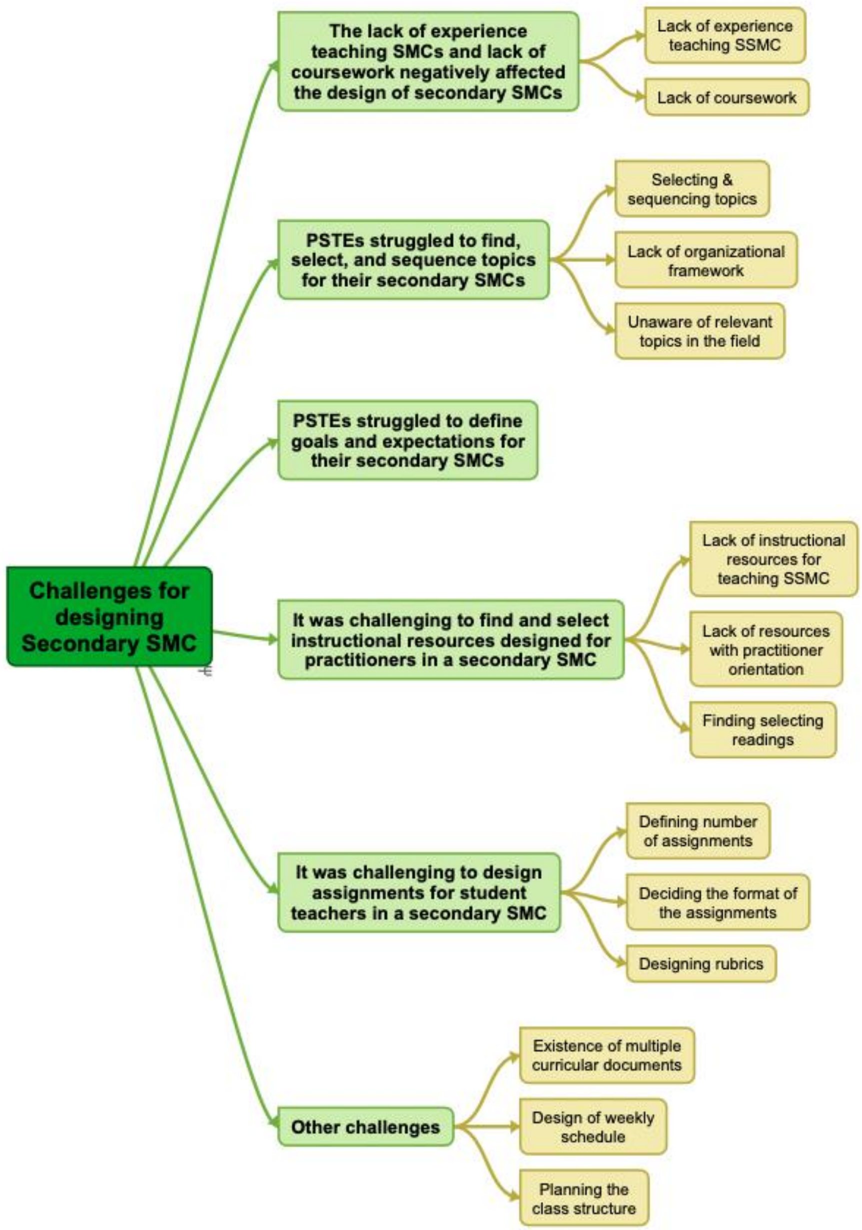

Figure 14. Thematic network summarizing the identified challenges presented by PSTEs during the design of SSMC syllabus (*SSMC: secondary science methods course*).

- **The lack of experience teaching SMCs and lack of coursework negatively affected the design of secondary SMCs**: PSTEs mentioned some challenges related with their lack of experiences. For instance, one of them mentioned that his/her lack of experience teaching a SSMC made it difficult for her to select activities and assignments for this class. Another PSTE argued that since s/he is in the first years of his/her doctoral program, s/he hasn't taken enough courses to have an idea of what are the relevant topics to include in a SSMC.

Selected quotes
"there is another limitation for me, because I've never taught methods class before, I have some ideas of what it looks like. But... when it comes to like teaching, you gotta think about time, you know, and you don't want to overwhelm students with assignments... with content, like, you got to be really concise, brief."
"As a first-year student, I feel like there are many things I have not learned. I am looking forward to taking the curriculum course."

- **PSTEs struggled to find, select, and sequence topics for their secondary SMCs**: PSTEs expressed different challenges related to the contents of their ESMC. The most prominent content-related challenge was selecting and sequencing the content. These challenges had to do with the limited time during the semester, the fact that there are many different topics that can be taught in this class, and the lack of an organizational framework to select and sequence contents. Also, one PSTE mentioned that s/he was not aware of what are the relevant topics in the field, since s/he has not taken enough courses in his/her doctoral program yet.

Selected quotes
"I had many [assignment ideas]. And then, you know, I wrote them down, and then reevaluated, because... I have a lot of ideas... but at the same time, I had to think about my time, because I know I have like 10 weeks, I cannot incorporate all the assessments... that are in my mind... And I just... picked some of them... I do have some ideas and then select selecting important."
"did I mentioned topics... content topic issues? like selecting the topics. I think it's a big issue like, what kind of topic or what types, you know how many topics you are going to cover throughout the semester. That's a big issue"
"When designing a science method course, I think it is complicated to decide the sequence of the course, to determine the content of the course"
"I have some ideas, I could not, organized really well. So when I have idea here I type here and then I move and type somewhere else"
"Before that, I just have some... separate ideas, but are not able to combine them together."

- **It was challenging to find and select instructional resources designed for practitioners in a secondary SMC**: Most of the PSTEs designing SSMC also mentioned that they had challenges related to the instructional resources for teaching this class. They argued that they had several teaching resources for their own learning, or for teaching science to K-12 students, but they have not developed instructional resources specifically for students of SSMC. One of them also pointed out that the teaching resources s/he has collected from different courses during his/her doctoral degree are not appropriate for student teachers, so s/he needs to find and select more practitioner-oriented resources, which was a big challenge for him/her too.

Selected quotes
"The second thing I realize is, I have many materials on my laptop, but it's mostly for my learning. Yeah. And for some is for high school students. But if I teach a course for undergraduate or masters students, I need... completely different materials. And, yeah, I did not think before working on this, I did nothing like. I will need some papers from practitioner journals."
"Another difficulty is that I do not have materials that are appropriate for undergraduate or master students. This makes it hard for me to have a clear picture of how the teaching will be."
"the courses I took at [University] are helpful for my teaching in the near future, but I cannot use the materials from the courses to teach undergraduate students. I will need to find some papers from practitioner journals."
"And the second thing [challenge] is about finding reading material for them [student teachers]. Like, for now, all what I have is more about research papers. I have only a few from, like, theoretical, I think if they are undergraduate is better to give them papers from like practitioner journals... but I don't have many papers... most suitable for teachers."
"I think it's a hard job because I need to select them and find a good one for my students... It's a selecting process, and he requires a lot of energy, and it's very difficult."

- **PSTEs struggled to define goals and expectations for their secondary SMCs**: Defining goals was also a challenge in the design of SSMC. More specifically, the wording of these goals. One participant mentioned that it was challenging for him/her to select the words to use in these goals, since some of these words may have strong connotations, like 'learning'.

Selected quotes
"When you talk about "hey let's write a bunch of objective", so sounds really easy, but actually is not an easy thing to do, because you gotta be really specific like, developing a cycle, how do you name it, for example, 'students will be able to develop skills'?, or 'students will be able to learn'?, because when you say like, 'students will be able to learn', it's a big assumption like how do you know they are going to learn?... the word learning is kinda you know... there's a lot of meaning in it... just course objectives is really kind of hard"

- **It was challenging to design assignments for student teachers in a secondary SMC**: PSTEs also presented challenges related to the assignments for their SSMC. They had issues defining the number of assignments during the semester, the format of these assignments, and designing rubrics. One of the participants has graduate training in educational assessment, but s/he also expressed challenges for designing assignments and rubrics.

Selected quotes
"that was another limitation, I struggled a lot, because I was thinking, I created six assignments at beginning and then I thought like oh this is too much, you know, like, when I put the due dates and stuff. It is really difficult just to decide"
"And then like, you gotta think... how many questions do you ask, what do you ask them to turn in, like is it gonna be like a video?... or paper? Or how many pages? All that stuff, so it took a while for me to finalize all this stuff."
"after the assignments, I... I thought about rubrics like how I am going to evaluate those assignments, that's another big challenge."
"I spent a lot of time thinking how to develop a rubric for each assignment. Even though I had a master's degree in measurement and evaluation in education and was familiar with types of assessments and rubrics, developing rubrics for my science method course was a quite effort. One reason might be the fact that I have not had a chance to teach a method course or help an instructor with planning and teaching a science method course."
"When designing a science method course, I think it is complicated... to decide how to evaluate the students."

- **Other challenges**: Other challenges mentioned by PSTEs were the existing of multiple curricular documents (local, national) in the US context, planning the weekly schedule for the course, and planning the structure of each class.

Selected quotes
“I stuck with the NGSS and I noticed that I should be aware of the importance of learning the [local] Standards for preservice science teachers in the state of [state]. This is kind of a challenge for me because the NGSS and the standards of each state are something I learned [recently]”
"For a long time, I thought that the NGSS is the science curriculum. One year ago, I learned that it is not!"
"Something I need to improve on for my course is to pay more attention to incorporating the state standards into my teaching so that preservice teachers can aware of what is expected from them while they develop their own lessons and teach their students."

Factors influencing prospective science teacher educators' pedagogical decision-making when designing science method courses

Cross case analysis of factors influencing PSTEs' pedagogical decision-making

Similarities

Extra-personal factors

Factors identified in this study were organized into *extra-personal* and personal factors. Factors identified as *extra-personal* were those associated with external or contextual elements from where PSTEs took ideas to include in their SMC syllabus. Three main themes were identified for extra-personal factors in the three cases: existing syllabi, curricular and standard documents, and literature.

Existing syllabi were by far the most frequent extra-personal factor considered by PSTEs when designing their own SMC syllabus in the three cases. This is probably because it is a resource that could provide them with all the necessary elements they needed to design their own syllabus (contents and sequence, assignments, readings, online resources, etc.). Most of the time, participants considered SMC syllabi according to their level, although one participant from the secondary case used an elementary SMC syllabus. Some of them also considered science content syllabi (a biology syllabus in the elementary case) or other educational courses syllabi (in the middle school and secondary cases). PSTEs used these documents in different ways. In the elementary case, they used it mostly for selecting and designing activities, assignments, resources, and teaching strategies. In addition, a few of them also used the syllabus for sequencing the contents and organizing the schedule, as well as for time management (i.e. how much time to devote to each topic or assignment). In the middle school case, one participant used the syllabus for sequencing the contents as well, and to get "different and creative perspectives" ideas to implement in his/he syllabus. Another participant used it to structure the course. In the secondary case, PSTEs used these documents to organize their SMC, select and sequence the contents, think about objectives and the assignments, and decide the depth of the selected contents.

A second relevant theme for extra-personal factors was "curricular and standard documents" in the three cases. Even when these documents are designed primarily to guide teachers with curricular decisions in their classroom, and some participants believed that they are more helpful for K-12 classroom context than the design of SMCs, most PSTEs were able to use these documents to help them with the design of their SMC. Most of them considered national and local curricular documents, even when some of them did not know in which state or city they were going to be teaching. In those cases, they selected documents for the current state or city where they were located. PSTEs used curricular and standard documents for different purposes. In the elementary case, for instance, some participants used these documents to select and sequence science contents to include in their SMC, and to organize teaching modules based on the teacher competencies in the standards. Their reasoning to include topics from curricular documents in their syllabi was that teachers need to learn these contents since they may be assessed on this in the content part of their certification exam, and later in the future, they will need to teach these science contents. In the middle school case, one participant initially used a national curricular document (NGSS) as a primary framework to organize his/her course. S/he argues that education research is considered for developing this document, and that SMCs should be standard-based. Later on, s/he realized that this document was not the most appropriate framework to continue developing his/her syllabus solely based on this for organization purposes. In the secondary case, one participant used a national curricular document (NGSS) to get some ideas on how to implement three-dimensional teaching in his/her SMC. A few of them also recognized that curricular documents can be more useful for science teachers when they need to design their lessons, than for STEs when they need to design a SMC, given that these documents apply better to the K-12 classroom setting than the SMC setting.

A third relevant theme for extra-personal factors in the three cases was "literature", like textbooks, research papers, and educational theories and frameworks. Participants use these resources in different ways. In the elementary case, for instance, one participant used literature on research in science education to inform his/her "teaching strategies, scope, and sequence". Another participant used different textbooks (in elementary education, as well as secondary science) to select topics and the sequence of these topics. In the middle school case, two participants considered educational theories as a framework to guide their design of SMC (i.e. ambitious science teaching, constructivism, social constructivism). One participant assessed multiple theories as possible frameworks before making a decision (i.e. out of field teaching, culturally responsive teaching), but s/he struggled with combining these frameworks in his/her SMC. One of the participants also used science methods textbooks as a source of activities to implement with student teachers (like lesson plan activities), to select readings, and to align activities, with readings and assessment for each topic each week. In the secondary case, participants considered relevant topics from the literature in the field of science education as contents for their SMC syllabus (i.e. assessment, nature of science, equitable teaching, phenomena-based learning, inquiry-based learning). They also considered practitioner papers as a resource to teach teachers how different teaching methods apply to specific contents. Another participant considered an educational theory (metacognition) as content for the SMC to help teachers become independent active learners. This participant studied this theory in a cognition class s/he took recently. The same participant also used research papers to select more specific topics within the general list of topics s/he selected. For instance, for the topic of nature of science, this participant selected specific aspects or tenets of nature of science to include in his/her syllabus. Participants in the secondary case also used textbooks to select and sequence topics for their syllabi.

Some extra-personal factors could not be considered due to the nature of this study. Since PSTEs were designing a SMC for a hypothetical situation in the future, in some cases they could not consider the specific curricular context, like state or local curricular documents (although in most cases they considered national documents) or teacher performance standards. Some of them also mentioned that it was challenging to anticipate contextual aspects like the number of sessions per week and the number of hours of these sessions, as well as the number of students in the class, which made it difficult for them to plan some of the assessment activities, like micro-teaching activities or presentations. Most of them also could not consider specific requirements that a particular teacher preparation program may have for the courses they offer for student teachers. Having this contextual information would have informed some of their curricular decisions in their syllabi. **Figure *15*** summarizes the common extra-personal and personal factors influencing the design of SMC by PSTEs in the three cases.

Personal factors

In this study, *personal factors* were considered those teachers' internal factors they bring within their personal backgrounds, such as their past experiences teaching and learning experiences, interests, and beliefs. Three main themes were identified for personal factors in the three cases: learning experiences, teaching experiences, and research experiences.

One of the most important personal factors influencing their pedagogical decision-making process was their teaching experiences. All the participants have teaching experiences at different levels. Most of them are former K-12 teachers (except for one participant), so they were able to recognize from those experiences what is important for student teachers to learn in order to be effective science teachers. This factor was especially relevant for those without previous experience as teaching assistants or instructors of a SMC. For those participants who had experiences as teaching assistant or instructor of SMC, this experience was the most relevant factor influencing their pedagogical decision-making process, since these experiences provided them with content, sequence of topics, activities, assessments, readings, or other resources from where they could build and elaborate on to design their own syllabus. Just one participant in the elementary case considered his/her experiences as instructor of other science courses for student teachers. This participant never took or taught a SMC, but s/he was able to build up from the curriculum of other teacher preparation courses, since this was one of his/her closest experiences related to designing a SMC syllabus for student teachers.

A second important personal factor for participants was their learning experiences. This group of factors was especially relevant for those with little or no experience teaching science teachers in general, or as TA or instructors of SMC. Participants were able to recall their experiences as students and they used this information to guide the design of this course. More specifically, they included activities in which they engaged as student teachers for instance (teaching demos, inspiration boxes, reflection paper), to decide about the length of activities, or to think about the assessment for their SMC. Interestingly, just one participant in the secondary case recalled experiences from the SMC s/he took during their teacher preparation. Most of the participants took teacher preparation SMC during their teacher preparation. But even though the SMC they took could have been a good starting point since they needed to design a similar course, especially for those with limited experience in teacher education, this experience was not considered by most of the participants. This could be explained by the fact that for many of them, it has been several years since they took this class (3 up to 26 years ago). From their learning experiences as doctoral students, they considered topics, activities, and resources (readings) from their coursework to include in their SMC syllabi. Learning experiences as K-12 students were also a relevant factor for one participant in the elementary case during their pedagogical decision-making process. This participant has had limited experience with student teachers and took one SMC 8 years ago, which could explain why this experience as an elementary student was a relevant factor to inform his/her pedagogical decision-making process during the design of a SMC. One of them also considered their lack of experiences or learning opportunities during his/her teacher preparation programs to include this and fill some gaps s/he identified in their own teacher preparation (for instance, ways to practice inquiry, in the elementary case).

A third relevant theme identified in the three cases was the research experiences of PSTEs. At least one participant in each case considered their dissertation topics or areas they have researched during their doctoral program. These participants incorporated those topics as part of the content in their SMC syllabi, as activities, or they decided to include readings about those research topics. This contributed to making each syllabus very unique, given that their research areas were very diverse (for instance, teachers' identity development, out of field teaching, scientific practices, modeling).

Figure *15* summarizes the common personal and extra-personal factors influencing the design of SMC by PSTEs in the three cases.

Differences

There are no relevant differences in the general themes identified for the three cases in terms of the factors influencing PSTEs' pedagogical decisions when designing SMC. When we compare the subthemes, one difference is that science content courses syllabi were only considered as a source in the elementary case. The participant who considered this factor taught a science content course (life sciences) previously, thus s/he transferred many ideas/activities from that course to his/her SMC. In terms of their previous learning experiences as a potential factor, an interesting finding was that only in the elementary case one participant considered his/her learning experiences from elementary school. This participant recalled how his/her elementary teacher taught science. This PSTE had no experience as an elementary teacher, and minimum experiences with elementary SMC, which could explain why s/he was considering experiences from when s/he was an elementary student, since this was probably the most relevant experience for him/her in an elementary setting. Another factor exclusively observed in the elementary case was the consideration of teacher preparation standards in the design of elementary SMC. One participant used their local teacher competency standards as a framework to organize the topics of the SMC in modules. This participant has been instructor of records of elementary SMC for three consecutive years and has been involved in science teacher education for a couple of years, which could explain his/her familiarity with their local teacher competency standards.

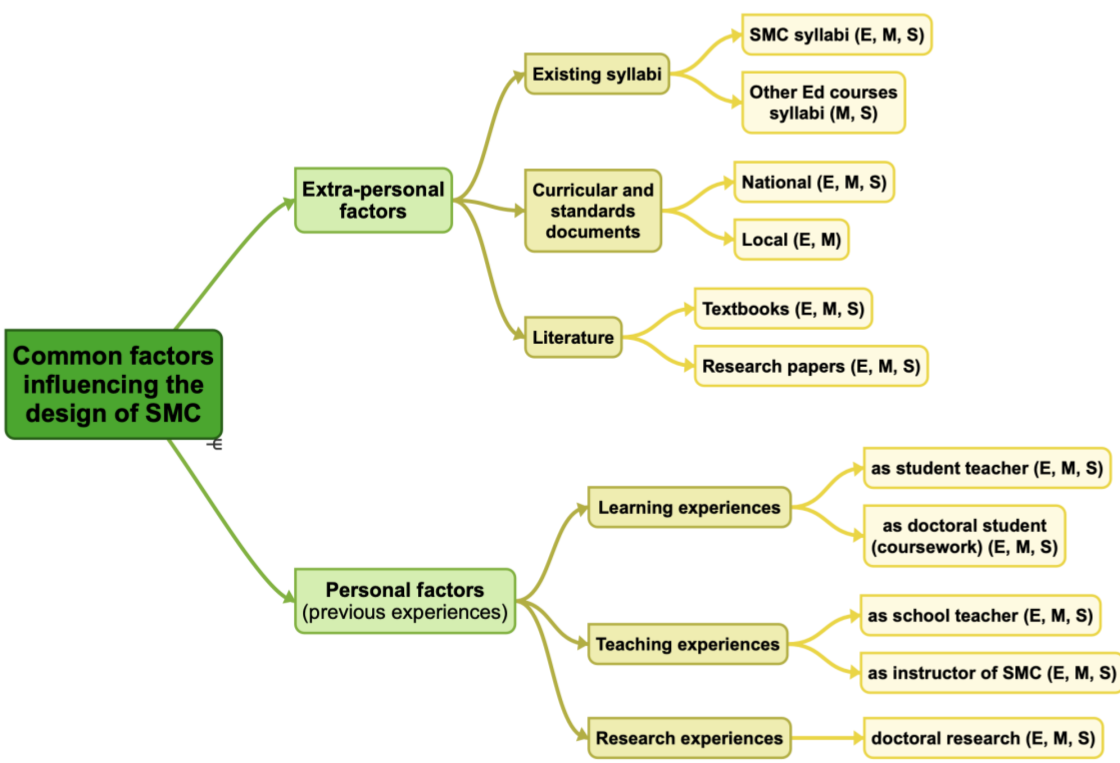

Figure 15. Thematic network summarizing the common factors influencing the design of SMC by PSTEs in the three cases.
(*E: Elementary case, M: Middle-school case, S: Secondary case*).

Elementary Science Methods Case

In the following sections I discuss the identified factors influencing PSTEs' pedagogical decisions when designing their elementary science methods courses (ESMC). The thematic network presented in **Figure *16*** summarizes these factors.

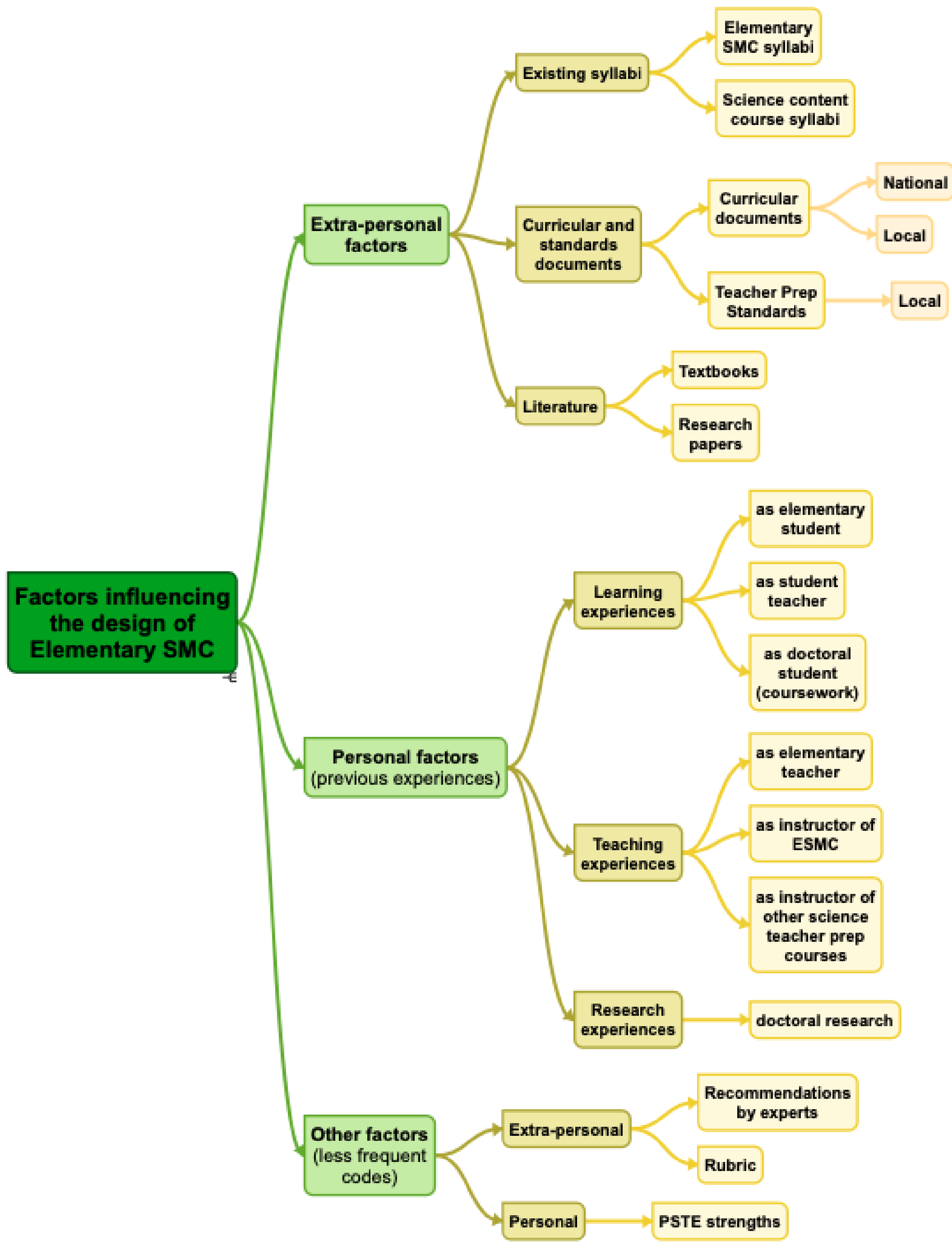

Figure 16. Thematic network summarizing the identified factors influencing the design of ESMC by PSTEs.
(*ESMC: elementary science methods course, PSTE: prospective science teacher educator*).

Extra-personal factors - Elementary case

- **Existing syllabi**: Existing syllabi was a relevant factor in the design of ESMC. Most of the times PSTEs used ESMC syllabi, but also one of them also considered a science content courses syllabi. Additionally, most of the times they used syllabi designed by other instructors, but one of them also considered a syllabus s/he designed and implemented in the past. The syllabi were used for different purposes. Mostly they were used by the PSTEs to select and design activities and assignments, to get ideas about teaching strategies and resources, and to define the schedule or sequence of contents.

Selected quotes
"I did use my mentor's previous syllabus as a starting point to kind of say okay, she taught this class for 30 years, so she probably has a decent idea of what she thought was important"
"So as a novice teacher educator, creating a syllabus for this first time, I definitely have felt the urge... to remain close to what someone before me has done"
"As a novice I want to stay close to what people have done before me. And then... as I start to learn the rules, as I learn how the game is played, I can start to make my own rules and build my own game board. But I need to get on a game board before I can make my own"
"I was looking at, like, others' experience, professor who has taught this class before, and how their syllabus looks like and how the content look like. So I've realized maybe elementary school teacher they didn't have a lot... I mean I know they don't have a lot of like science content, but I didn't know that I should add size contact client here. So then I kind of just followed what the syllabi that people used before."
"I think... if I'm really going to teach the class in the first year, I would just follow what other people did before, and then in the second year I will modify it, according to how the students reflect"
"I basically based on others' syllabi because I know those syllabi already has been used."
"I refer to other experienced professors' syllabus, who have taught this course before"

- **Curricular and standards documents**: Curricular and standards documents were another important factor in the design of ESMC. PSTEs used both local and national curriculum documents. Some of them used these documents to select and sequence science content, and also as resources for teachers to know what science contents they need to teach, but not as an organizational framework. PSTEs also used teacher preparation standards for designing their syllabus. For instance, one of them use these standards to create teaching modules based on the expected competencies for teachers in a standards document.

Selected quotes
"I was expecting, maybe they're going to teach in State... so of course I look at the State standard"
"I use them [the standards] as a resource that students [teachers] should know... people are going to expect you to know, and... you got to use those standards when you're building your own lesson plan, because one of the assignments... is building lesson plan, and whenever you're doing lesson plans, of course they need to look at the standard."
"The... state standards, those are for the kids. So that's just purely content and practices. So... those would be what they needed to know for their content part of the assessment on the certification exam but not necessarily on how to teach."
"I basically took the State [teacher] standards... we have competencies, or what the teacher should be able to know and do"
"we have the State teacher competency exam. So it's their certification exam. And so I basically took those competencies of what they list for methods of knowing, how to teach science... and basically made... little modules."

- **Literature**: Literature in the field was another important factor in shaping PSTEs' syllabi. They considered different textbooks on science methods mostly for selecting the topics or sequencing the contents for their ESMC. One of them also considered papers on teaching biology to inform his/her teaching strategies and sequence.

Selected quotes
"I looked at the two books I listed on the syllabus for the methods course, to see what topics they covered, and to see what topics were different in the elementary one versus the one that's designed for secondary."
"I utilized some textbooks to see how they approached the content and how they organized their own sequence."
"I use them [textbooks] for what kind of topics they were covering, and what order they discussed them in, to see how they built on them, because they didn't sequence them in the same way. Ultimately, I think I ended up following more of what the elementary one went with, adding in the other chapters in other books as well where they fit."
"I know what research says about teaching biology content and that informs my teaching strategies and scope and sequence."

Personal factors - Elementary case

- **Previous experiences**:
    - **Learning experiences** (as students): PSTEs considered a variety of previous experiences in the design of their ESMC. For instance, their learning experiences as students. One of them considered his/her experiences as elementary student, s/he reflected on what learning experiences worked well in elementary school. They also reflected in their learning experiences during their teacher preparation to make decisions about some of the activities and assignments. One of them also considered learning experiences during his/her doctoral degree.

S/he considered resources they explored in a teacher prep course during his/her doctoral degree.

Selected quotes
"I think back to how my former elementary school teacher taught science lessons, what was good and what was bad, and learn from those experiences as a student. I use the students' perspective to think about what conditions a good science teacher should have."
"how much time for teaching demo? I say 15 minutes because I have that experiences when I was a student in the education program, we did teaching demo in 15 minutes. So I though Hmm, it... makes sense if I have 15 minutes."
"since I didn't get this in my teacher preparation program, I explicitly incorporate ways to practice inquiry within the course and reflect on those experiences"
"I heard about them [books] in one of my classes that I took... for our Ph D program, we have a course on teacher prep. And one of the projects we did, we needed to identify textbooks, we could use to teach a course, not necessarily methods just what's out there."

- **Teaching experiences**: PSTEs also considered a range of different teaching experiences they had in the past to make decisions about their ESMC. For instance, they considered their experiences as elementary teachers. For some, the lack of experiences as elementary teacher represented a challenge during this process. For some PSTEs, their experiences as instructor of this class were another factor to make changes to their syllabus. Based on the implementation of their syllabus, they make changes to the structure of this course. PSTEs who has not taught an ESMC before were also able to identify this as a factor to make changes to their syllabus in the future. Finally, their experiences teaching other teacher preparation course were also considered in the design of their ESMC.

Selected quotes
"as I am teaching it, that's when I realize that 'Oh, I should have added this in my course, and I should have added that right?', and so I missed some, a lot of stuff and I'm like, "Oh... I needed to add that", you know, So now you learn a lot but then it's not until you're really enacting it"
"I don't think I would do anything differently on this first draft. But if I'll teach it for a semester, then, there probably be some things I would change"
"there were numerous times during the process of determining the scope and sequence that I reflected on science teacher prep courses that I have taught in the past to think about how I approached topics with them or discussed pedagogy with them in order to determine how I could do the same in this methods course"

- **Research experiences**: Finally, PSTEs' research experiences also influenced on the design of their ESMC. For instance, one of them added an assignment based on his/her dissertation topic. And also, the topic of his/her dissertation is something s/he tried to incorporate in the ESMC.

Selected quotes
"I added... the autobiography, because my dissertation is on identity teachers' identity and developing that. And so, I'm basically using the methods course this next semester as... an experience in identity development. So I'm going to be more explicit in getting them to understand that this is all part of helping them to build their confidence and identity"

Other factors - Elementary case (less frequent codes)

- **Other factors** mentioned by PSTEs were recommendations by experts in the field, their own strengths or topics they felt confident with, and a rubric / checklist for the design of syllabi.

Middle School Science Methods Case

In the following sections I discuss the identified factors influencing PSTEs' pedagogical decisions when designing their middle school science methods courses (MSMC). The thematic network presented in **Figure *17*** summarizes these factors.

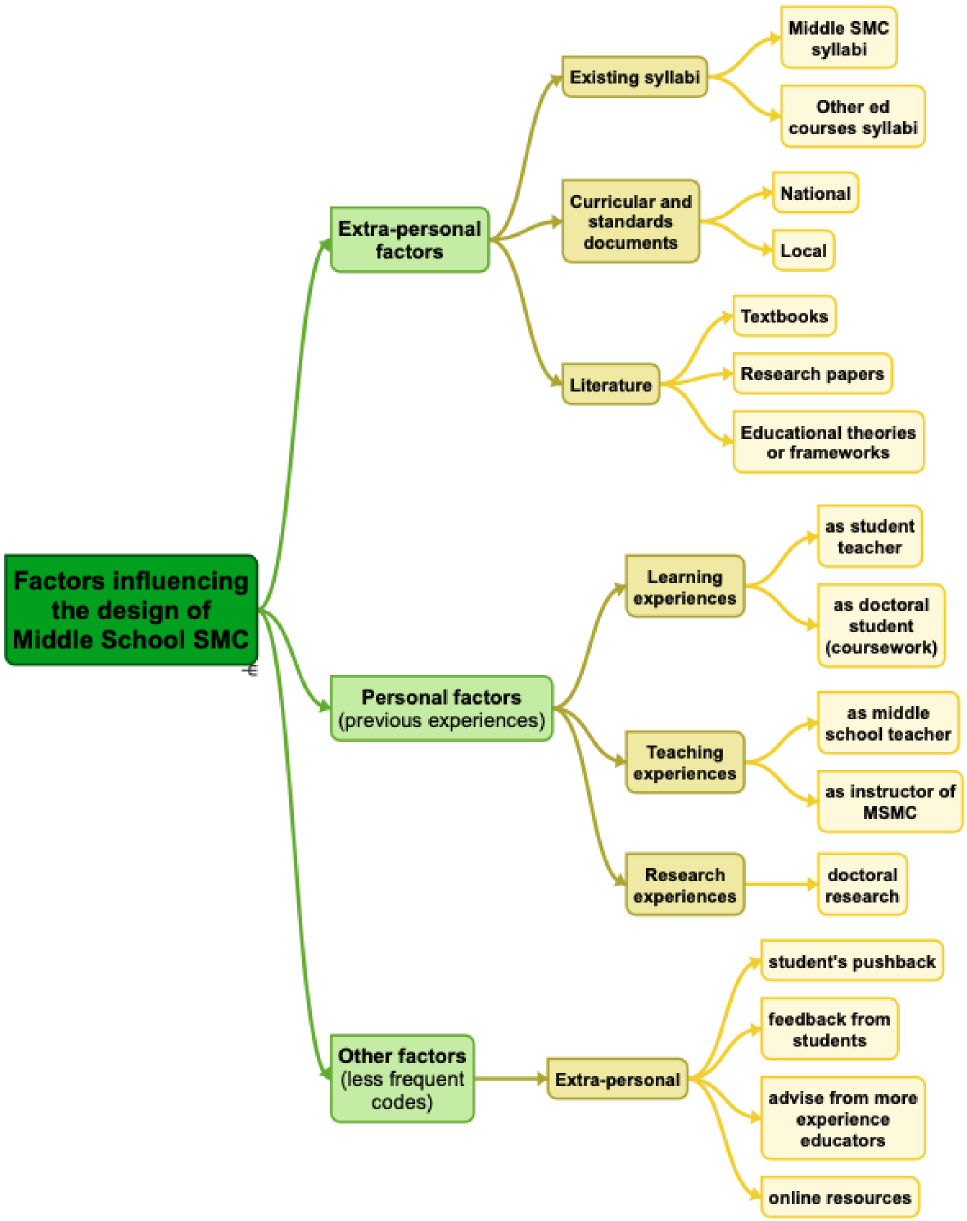

Figure 17. Thematic network summarizing the identified factors influencing the design of MSMC by PSTEs.
(*MSMC: middle school science methods course, PSTE: prospective science teacher educator*).

Extra-personal factors - Middle school case

- **Existing syllabi**: Existing syllabi was a relevant factor in the design of MSMC. All of the participants mentioned that they considered syllabi designed by other professors. Most of the times they considered MSCM syllabi, but one of them also considered syllabi from other courses. Some of the reasons they mentioned for using this resource are the fact that they liked those syllabi and to avoid students' push back. They mostly used this resource for sequencing content, structuring the course and getting some new perspectives or ideas to implement in their course.

Selected quotes
"[I used] Dr. X and Dr. Y [syllabi], or the other professors I took classes before So, I have some syllabus I really liked it and I combined [them]"
"I copied his [syllabus] because I was nervous and if I was really strict about it... I would get pushed back, because I felt like I had to model his."
"I asked faculty that had taught the course before, I asked for old syllabi and then used that to help me structure."

- **Curricular and standards documents**: Only one of the PSTE who designed MSCM mentioned that s/he considered a national curricular document in the design of his/her syllabus. S/he mentioned that s/he used the NGSS as an organizational framework.

Selected quotes
"I started with the framework, I thought I wanted to use NGSS... I have used the NGSS as a primary framework"
"the methods course should have a theoretical framework and should be standards-based."

- **Literature**: PSTEs who designed MSMC also considered the literature for designing their syllabi. They used textbooks for instance, mostly for selecting activities and readings for the course. They also considered different educational theories as an organizational framework. For instance, they considered ambitious science, constructivism and social constructivism. One of the PSTEs also considered papers in the field of science education for reading about theoretical frameworks that can be useful for his/her MSMC.

Selected quotes
"I think, my own idea to do two lesson plans instead of one, because I did read and a few people had done two lesson plans, one of the books that I read, that book also had two lesson plans"
"for the readings, I was basically looking at books designing, so I just searched designing methods courses, I looked at middle and at the secondary level and looked at some Elementary"
"I thought, like, ambitious science teaching is more contemporary, it's like more accurate, the 5E model has been there for a long time. So I also looked at PCK. But then I was like, No, I don't want to do this. Everyone, everyone's been doing it."
"I'm definitely leaning towards like being social constructivist. So like having them have opportunities to wrestle with information and be more active in it. Like I like doing debates."
"So I decided to go with ambitious science teaching, and the constructivist approach, and made it standard based."

Personal factors - Middle school case

- **Previous experiences**:
    - **Learning experiences** (as students): Another factor were PSTEs' learning experiences as student teacher or as doctoral students. One of

them included activities they did during his/her teacher prep program, and other included activities that the professors used with them in his/her doctoral program.

Selected quotes
"you'll notice I did inspiration boxes with them. And that was something we did as... an extracurricular when I was in my teacher prep program. And essentially, we... decorated boxes. And I brought it to my classroom with me, and you put things in there that inspire you to keep teaching."
"I think where I was maybe uniquely poised to help them was that I was also in the teacher prep program. So I was in that class [SMC] when I was in college, and I knew what mattered and what helps me and I knew what didn't."
"Then there were certain other activities which I found in the books that I read and others which the professors had used with us in the Ph.D. program classes."

- **Teaching experiences**: Teaching experiences were another important factor. PSTEs considered their experiences teaching middle school science. They considered lesson plans and activities they used as middle school teachers, and they included those in their syllabi. They also considered experiences teaching MSMC, like the feedback they received from students to make modifications to their syllabus.

Selected quotes
"I just sort of thought about what I did in the classroom, and I had specifically taught both of the contents to the age group. So I went through all my lesson plans, and then identified some that I thought were really useful in the classroom."
"the activities that I chose to do with them I did in my classroom like and so they have to make those same decisions in the future."
"once I had planned my outline for the course, I had to plug in with the activities. That was the, I wouldn't say easy but I would call it as an interesting part, because now I had all of those activities which as a teacher I have successfully done with my students, and I could include those."

"I don't I don't know if there was like a framework, more that I kind of felt guided a lot by my experience in the classroom."
"So those were three things that I hadn't planned for, but based on the survey, I decided were really important to the integration."
"But I think like, I definitely wanted to listen to the students and then modify the course based on what they needed."

- **Research experiences**: Research experiences also affected some decisions when designing MSMC. One of the participants, for instance, included topics that are related to his/her doctoral research, and actually this topic was the main focus of his/her MSMC syllabus.

Selected quotes
"The most important part of my methods course is that it is meant specially for [research topic] who may be teaching Physical Sciences [research topic]."
"This course is unique as it is designed for teachers who may potentially teach physical science [research topic] because there is no other such Physical Science methods course that is tailored specially for [research topic]."

Other factors - Middle school case (less frequent codes)

- **Other factors** mentioned by PSTEs were students' pushback, advise and feedback from more experience educators, feedback from students and some online resources like website offering science instructional resources (NSTA), science websites and news.

Secondary Science Methods Case

In the following sections I discuss the identified factors influencing PSTEs' pedagogical decisions when designing their secondary science methods courses (SSMC). The thematic network presented in **Figure *18*** summarizes these factors.

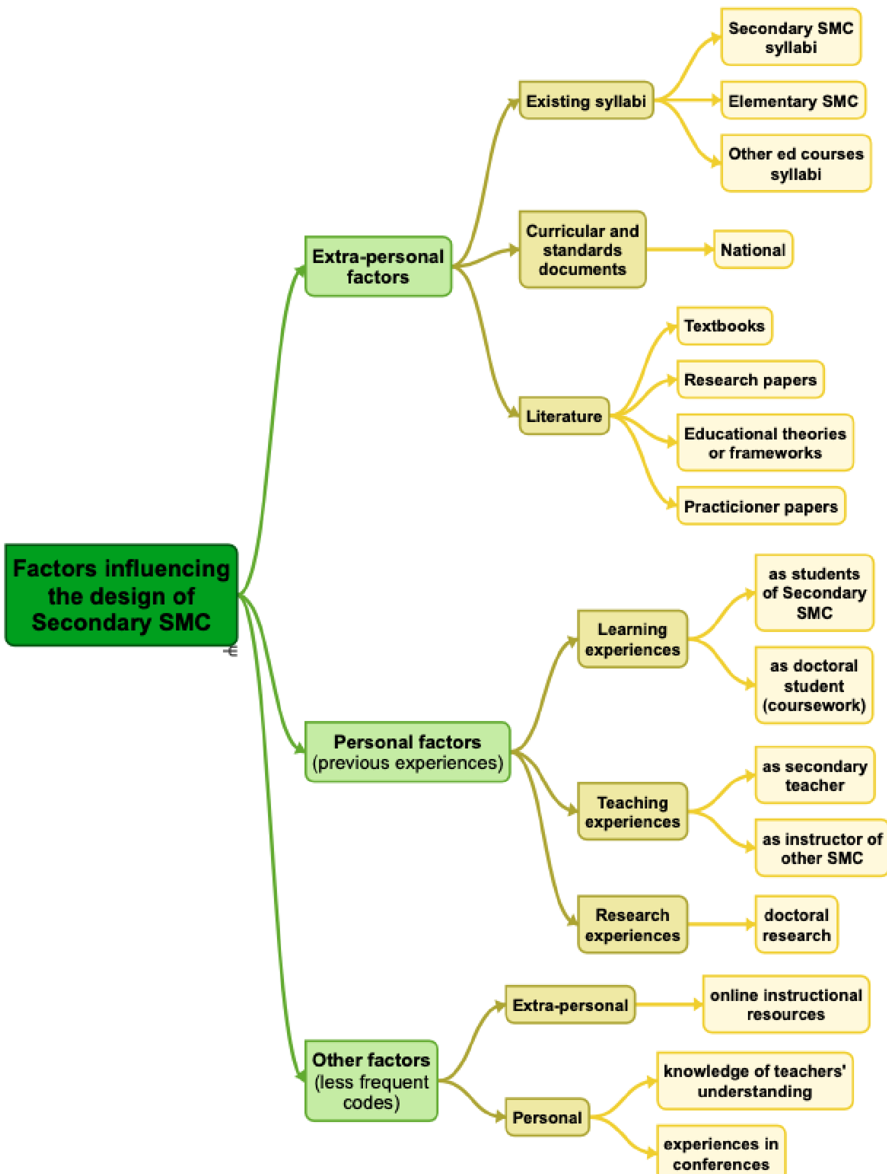

Figure 18. Thematic network summarizing the identified factors influencing the design of SSMC by PSTEs.
(*SSMC: secondary science methods course, PSTE: prospective science teacher educator*).

Extra-personal factors - Secondary case

- **Existing syllabi**: Previously designed syllabi were an important factor for PSTEs when designing their SSMC. PSTEs considered syllabi for EMSC as well as SSMC designed at their university or other universities. They also considered syllabi from courses they have taken before, as well as syllabus from other courses and other universities. PSTEs used these documents to organize their SMC, select and sequence the contents, to think about objectives and the assignments, and to decide the depth of the selected contents.

Selected quotes
"while selecting the ideas, you know, selecting among those ideas I developed first, I looked at the syllabus I have from previous like instructors"
"I was trying to see what is the priority, like differences and how I'm thinking and how the instructor in the past taught the class. So I... had guidance for me, how I'm going to think about this course"
" Her syllabus for elementary level science teachers. So I looked at objectives how she is talking about like objectives for elementary level science teachers for service science teachers. And then I looked at assignments."
"I had a chance to examine different syllabi for science methods courses that were taught in different universities in the United States during one of my doctoral seminar classes"
"I kind of look at back my syllabus for my classes that I took before."
"she asked us to kind of collect, so many different syllabi. It can be for science content courses or it can be for methods classes... so that we can see all the differences and priorities, you know, across different syllabi. So, and then, I think that kind of really helped me to, you know, just review all that syllabus that I collected for that class. They were from like different universities, different professors"
"I will refer to how they organize their syllabus. So what to say at first what to say then, for example"

- **Curricular and standards documents**: Curricular documents were considered important for one of the PSTE. S/he mentioned the NGSS as a source of information to improve their syllabus in the future, by incorporating some new perspectives or ways of teaching science (i.e. three-dimensional learning).

Selected quotes
"And for looking at the NGSS... it will help me to think how I can integrate some, for example... this three-dimensional teaching in my teaching. So, I will consider use more practice or something else to improve my course"

- **Literature**: PSTEs also mentioned textbooks as another factor. For instance, one of them mentioned that s/he used textbooks to help him/her to conceptualize the broad scope of topics that can be included in his/her SSMC. One of them used research papers too to check if a content was missing in the syllabus and also to understand the central idea of those contents. Finally, one of them also considered educational theory (metacognition) between the topics to discuss in his/her SSMC.

Selected quotes
"So I think the textbooks I'm referring in a syllabus, they are... talking about topics, mostly what do you cover, but it wasn't like that, like I opened the book and then look at the content list and then pick the topics from there... it was more like for example, let's talk about triple AAAs like that policy document emphasizes the importance of understanding nature of science... So what is the emphasis about learning science, so like inquiry based learning, what do you include when you talk about in inquiry learning?... so I was kind of conceptualizing the whole thing, not the like specific topics"

"I use them [papers] to check if I forget something important. I use them to make sure I use the correct terms and kind of like helped me to remember... So, I make a note for myself about what is the main idea of the content."
"for me the metacognitive strategies to become an independent active learner, that part for me is really important, but I did not see it clearly in other syllabi... And I... wonder, I don't know if I'm allowed to ask, and then I think it's academic freedom. So yeah, I can decide to add that content to my syllabus."

Personal factors - Secondary case

- **Previous experiences**:
  - **Learning experiences** (as students): Different types of learning experiences influenced on PSTEs designing SSMC syllabi. For instance, some used their experiences as students of SMC to have an idea of what is taught in a SSMC. PSTEs also considered their learning experiences in other courses, and the included some of the contents or assessment strategies of those courses in their SSMC syllabus.

Selected quotes
"when I take class, I really care about like my attendance and stuff so I know what is like average, what is acceptable like how many times if students miss the class it's probably a problem. This is something like coming from my own experience as a student."
"I still remember a little about what... we studied for that course [SMC]... So I have a sense of what it is, so it did not take me much time to figure out what I should put into the syllabus"
"I tried to recall the science method courses I had taken"
"And I can say the psychology for teaching and learning that course is really helpful for me when I designed the syllabus. The course is mostly about instructional approaches. And I kind of like it. It makes clear for me about how to pick and appreciate an approach, depends on the kind of knowledge on the existing knowledge of the student."
"what I have been assessed... I when I was a student... That will help me to design how to assess the students."

- **Teaching experiences**: Different types of teaching experiences also helped PSTEs to shape their SSMC. For instance, they considered their experiences as schoolteachers for selecting topics or designing activities for their course. Also, one of them took ideas for activities from his/her experiences as co-instructors of an ESMC and s/he adapted these activities for secondary teachers.

Selected quotes
"Mostly is from my own experiences as a teacher, like I have a sense about what is important."
"And my previous experiences, I think it will help me to get some ideas to design my activities. For example. I try to let my students to design a demonstrative instruments to use in the physics lab. So it's what I have done before."
"I thought about my own experiences as a teacher and as a student. This helped me to figure out what the course should include."
"for example, assignment, one was about learning from cases. This is something I learned from back to Dr. X and X, whom I co-taught elementary level science class. So I really like that idea and I saw that it was really helpful for elementary level service teachers. And then I thought, I'm gonna do the same thing with high school pre-service teachers... and then, you know, incorporate more kind of resources and some kind of modification, because my audience is going to be high school teachers"

- **Research experiences**: One of the participants also considered topics related to his/her doctoral research. S/he included these topics in his/her syllabus because s/he considered they were important emergent topics.

Selected quotes
"my research is like more about scientific practices, especially modeling. So, and then I read the literature about that, I know it's kind of really emerging, it's important people write about it, do research about it. So I think those kinds of stuff... I just want my pre-service teachers, just be aware of those kinds of stuff because in the future if they go into like professional learning opportunity environment, they will be learning about talking about those kinds of stuff so I thought, they will have the fundamental like ideas and knowledge, if they take this course from me"

Other factors - Secondary case (less frequent codes)

- **Other factors** mentioned by PSTEs were experiences in professional and academic conferences, online instructional resources (NSTA), and knowledge of teachers' understanding.

Selected quotes
"But I think if I can go to NARST next year, it will broaden my horizons. So maybe I will integrate more elements in my syllabus."
"I believe my own readings and my participation in academic conferences (NARST, GSTA, NSTA, etc.) helped me a lot to create a course bibliography."
"when I really sit down to make the syllabus. I thought that I want to make that part more helpful for the students. So I picked something that a more like. For many teachers, they feel like cellular respiration is something difficult to teach. So I think it's not just so to, how to teach, like, give them some content knowledge to."

CHAPTER 5

5. DISCUSSION, CONCLUSIONS, AND IMPLICATIONS

Discussion and Conclusions

Dimensions/topics considered by prospective science teacher educators when designing a science method course

One of the purposes of this study was to characterize the dimensions/topics considered by prospective science teacher educators when designing a science method course. Similar to what was found in the review of literature, PSTEs considered a wide range of diverse topics and dimensions to include in their SMC syllabi. Participants' background and experiences influenced their decisions about these topics. The overall picture of the three cases shows that PSTEs included content that represented all dimensions considered in the pentagon PCK model (Park & Oliver, 2008a), most of the professional knowledge bases, and more.

These findings suggest a close alignment between the topics selected by PSTEs in their SMC and the PCK dimensions considered in this study. This is similar to the alignment that Sickel and Witzig (2017) found between the topics taught in these courses and the components of PCK models, in an analysis of different SMC from different continents. Given this diversity, the PCK dimensions seem to be an implicit framework for STEs when designing their SMC, especially for the selection of topics, since most of the participants considered most of the PCK dimensions in their courses. These findings add empirical value to the explicit use of PCK as a framework for planning SMCs.

When we look at the findings of the aggregated cases (**Figure *7***), there is a clear lack of emphasis on the '*Knowledge of assessment of science learning'* (KAs) dimension, compared with the other four PCK dimensions. There were fewer participants in the three cases that considered this dimension. A potential explanation for this is that most of the participants haven not taken assessment courses specifically for science in graduate school by the time data was collected for this study, which may have made challenging for them to select science assessment-related topics. Actually, some participants in the elementary and secondary cases expressed that designing assessment activities or rubrics for their SMC was a challenge, which can be related to the lack of emphasis on science assessment knowledge content. According to a review of 64 science education doctoral programs, it was more common that doctoral programs do not require a course in assessment in science education (Jablon, 2002). Only 11 out of the 64 reviewed programs had this requirement. Also, participants in the three cases (half of the total participants) included general assessment contents, which may have left less room for science specifics assessment topics. Additionally, it is common that student teachers take a class on assessment as part of the general pedagogy curriculum during their teacher preparation program, depending on the country or university. This is something that participants may have had in mind when designing their SMC syllabi and they could have decided to emphasize other science pedagogy areas. Additionally, according to the literature review conducted for this study, it is not common to have an emphasis on assessment in SMCs, with some exceptions (Brower, 2012).

Science curricular documents or standards were a very important component of SMCs syllabi in the three cases. PSTEs used these documents for analysis or discussion activities. They argued that it was important for student teachers to be familiar with these documents since they contain the knowledge teachers are expected to develop, and they will have to plan their teaching based on these documents. Considering all the other areas of science teacher preparation (content knowledge, science pedagogy, pedagogical knowledge, practicum experiences), science pedagogy courses seem to be the most appropriate context to study and discuss curricular documents specific to science, since these documents are integrating science content with pedagogical approaches (Anderson, 1997). In this sense, SMCs provide a very suitable context to study and discuss these documents, and to get student teachers familiar with them. It is expected that science teacher preparation programs provide student teachers with an understanding of the theoretical principles and concepts that support these curricular documents (Allan, 2017). While it is unclear if STEs are considering national science education standards in the design of their SMC (Smith & Gess-Newsome, 2004), the sample of participants in this study did consider these documents in their syllabus in different ways during the design of this course.

In the cross-case analysis, it was observed that it was more common for participants from the elementary and middle-school cases to include science content knowledge (100% of participants) compared with participants from the secondary case (66% of participants). It is not uncommon to see this situation in elementary or middle school teacher preparation programs. It is common for instructors of SMCs in these teacher preparation programs to cover science content knowledge, in addition to science pedagogy contents (Lee, 2010; Santau et al., 2014). This is because many times student teachers in elementary or middle school teacher preparation programs may not have taken enough credit hours of science content courses during their preparation (Allen, 2003; Palmer, 2002), and consequently they may not have a strong background in science (Fensham et al., 1991) and they may not feel qualified or prepared to teach science after graduating from teacher preparation programs (Weiss et al., 2001), so instructors need to address these gaps in the SMCs.

It was interesting that according to the literature review on SMC, out of twenty-four studies selected, only two of them incorporated diversity, equity, and inclusion (DEI) topics in the SMC (Mensah et al., 2018; Yerrick & Hoving, 2003). This suggests a lack of emphasis on these topics in the context of SMCs. This is similar to what was found in a literature review of elementary SMCs (Davis & Haverly, 2022). The authors concluded that this is an under-researched area, and they identified a need for more studies exploring "how elementary science methods courses can shift preservice teachers' beliefs, attitudes, knowledge, and practice of culturally sustaining pedagogies" (p. 88).

In contrast to these findings, participants from the three cases (three in the elementary case, two in the middle school case, and one in the secondary case) considered different DEI topics in their SMC syllabi. They considered topics like culturally responsive teaching, social justice in science, ethical, cultural, and social issues in science teaching, and equality-equity issues related to science (see **Table *7***). The inclusion of these topics by participants of this study aligns with the suggestions made by Davis and Haverly (2022) for SMCs based on their literature review. They suggest learning about leveraging children's linguistic and cultural diversity in SMC, focusing (extensively) on multicultural science education, and connecting to culturally and linguistically diverse field sites.

The contrast between the lack of emphasis on DEI topics found in the literature and the findings of this study may be explained by the relevance that DEI has gained in research in education in the last years, which may have influenced participants' pedagogical decision-making to include DEI issues in their syllabi. Additionally, the fact that most of the participants come from underrepresented groups in science education research (60% of Asian, South-Asian, and Middle eastern women) could have influenced their willingness to include DEI topics in their SMC. In this sense, Davis and Haverly (2022) highlight the importance of diversifying science methods instructors as a supportive design feature to work toward a next-generation vision of rigorous, consequential, just, and equitable science teaching.

Challenges faced by prospective science teacher educators when designing a science method course

The second purpose of this study was to identify challenges that prospective science teacher educators encounter when designing a science method course. Out of 5 themes identified for challenges, 4 common challenges were identified in the three cases. These were: lack of experience-related challenges, content-related challenges, resources-related challenges, and assessment-related challenges. From the subthemes of these four challenges, there were two common specific challenges for the three cases: “selecting and sequencing the topics” and “the lack of an organizational framework or national standards for science teachers”.

According to the literature review, science pedagogy courses are underrepresented in science teacher preparation curriculum. They represent the smallest proportion of the coursework. In most countries, it represents less than 15% (Cofré et al., 2022), including here the USA. Consequently, many times, science teacher educators need to decide what contents to include in a single and compressed SMC that can goes from 13 to 15 weeks (Lee, 2010). This can make challenging, even for experienced STEs, to decide what topics to include in SMCs (Lee, 2010), so it is not surprising that the PSTEs in this study presented challenges to select and sequence contents for their SCM as well.

These two challenges identified in the three cases (selecting and sequencing the contents, and the lack of a framework to help them organize the topics) are related to their understanding of the curriculum of SMC. These findings suggest that the main challenges that PSTEs faced are related to the “curricular knowledge for teaching methods courses” dimension from the PCK model for teaching science teachers (Abell et al., 2009). Since it is common for STEs to teach elementary, middle school, or secondary SMCs at some point in their careers (Abell et al., 2010), it is important for them to be familiar with the curriculum of these courses. Abell et al. (2010) argue that the different dimensions of the PCK model for teaching science teachers should be explicitly addressed during the doctoral programs for STEs. According to the findings in the sample of participants of this study, the dimension of “curricular knowledge for teaching methods courses” seems to require special attention in doctoral programs, since this was a common theme across the three cases. In this regard, Abell et al. (2009) have proposed that one of the professional knowledge standards for STE should be developing knowledge for teaching preservice teachers, including here knowledge of methods course curriculum. In addition to this and according to the review of literature, the fact that the contents of these courses are typically very broad and diverse could have contributed to making challenging for participants to select and sequence topics for their course. Participants of the study have had teaching experiences where they had to design lessons and instructional resources based on curricular documents with defined teaching units. This time, they had to design a course without having a defined curriculum, which made this task challenging for them. It is worth mentioning that only one PSTE in the secondary case mentioned that s/he was not familiar with the contents relevant for science teachers in the context of a SMC, which suggest that in general participants in the three cases were familiar with the contents that are relevant in a SMC, but they just struggled with selecting and sequencing these contents.

Another challenge expressed by participants in the elementary and secondary cases was “designing assessment and rubrics” to assess student teachers in their SMC. They expressed different issues like defining the number and format of assignments, and time management issues like deciding how much time to devote to each activity. An explanation for this could be their lack of experiences teaching SMCs. Only one out of four participants in the elementary case, and one out of three participants in the secondary case have been TAs for a SMC. This challenge is related to the dimension of “knowledge of assessment in methods courses” in the PCK model for science educators (Abell et al., 2009). This dimension is also considered in the *Professional Knowledge Standards for Science Teacher Educators* (Lederman et al., 1997). These standards propose that “the beginning science teacher educator should possess expertise spanning a variety of assessment approaches, including "traditional" and alternative assessment” (p. 237). Being instructors or TAs for a SMC during their doctoral studies, and having their professors explicitly address this PCK dimension for science educators could have contributed to developing their knowledge of assessment in methods courses.

None of the participants expressed challenges that could be related to the "knowledge of instructional strategies" dimension in the PCK model for educators. This could be explained by the extensive teaching experience (K-12 and college level) that all the participants have. Additionally, since this study is focused on the design process of the SMC and not on how it is taught or implemented, it is possible that these types of challenges were not evident at this stage.

Potential factors influencing prospective science teacher educators' pedagogical decision-making process when designing science method courses

Extra-personal factors

The third purpose of this study was to identify potential factors influencing prospective science teacher educators' pedagogical decisions when designing a science method course. For extra-personal factors, three themes were identified in the three cases: existing syllabi, curricular and standard documents, and literature. The most prominent factor influencing the design of SMC across cases was existing SMC syllabi. PSTEs used these syllabi mostly for defining the goals and contents of their SMC, but also for selecting and designing activities, assignments, resources, and teaching strategies. This suggests that their "curricular knowledge for teaching methods courses" is highly influenced by syllabi designed by previous instructors of this class, in contrast to more formal learning experiences in their doctoral program explicitly addressing the curriculum of SMC. While it is true that the coursework during their doctoral programs was a factor identified for the three cases, it seems that these learning experiences helped them to be familiar with some of the contents relevant for science teachers (i.e. improved their "subject matter knowledge of science and science teaching"), but not necessarily with how these contents can be sequenced or implemented in the context of a SMC ("curricular knowledge for teaching methods courses" dimension from the PCK model for educators).

A second relevant extra-personal factor in the three cases was "curricular and standard documents." They used these documents for different purposes, like selecting and sequencing contents, organizing modules for the course, or as a general framework. Despite these documents are not intentionally designed to guide the creation of SMCs, participants managed to use these documents as organizational frameworks. And a few of them recognized that curricular documents are more useful for science teachers to design their lessons than for STEs to design a SMC, given that these documents apply better to the K-12 classroom settings than a SMC context. These findings could suggest a lack of more formal sources or learning experiences during their doctoral programs to help them develop their “curricular knowledge for teaching methods courses.”

A third extra-personal factor identified in the three cases was "literature". For instance, textbooks, research papers, and educational theories and frameworks. Participants used these sources with different purposes, like to inform their teaching strategies and scope, to select and sequence these topics, as a framework to guide their design of SMC, as a source of activities and readings, among others. Literature in these three cases was contributing to their “Knowledge of instructional strategies for teaching methods courses” and “Knowledge of curriculum for teaching methods courses.”

Only one participant in the secondary case considered teachers’ understanding or conceptions for designing SMC, which could be related to the “Knowledge of teachers’ understanding of science and science teaching”, which is another dimension of the PCK model for educators (Abell et al., 2009). More specifically, s/he decided to include a particular topic (cellular respiration) because s/he considered this is a topic that is difficult to teach for teachers. Knowledge of pre- and in-service teachers backgrounds as learners has also been recognized as part of one of the four knowledge domains for STE (Mork et al., 2021; Smith, 2000). The fact that only one participant considered this dimension during the syllabus design process suggests that the "Knowledge of teachers’ understanding of science and science teaching" is something that they are not considering for designing their SMC and could be improved through formal learning experiences in their doctoral programs.

Personal factors

The other group of factors identified in this study were personal factors. Three main themes were identified for personal factors in the three cases: learning experiences, teaching experiences, and research experiences. One of the most important personal factors influencing their pedagogical decision-making process was their teaching experiences. Most of them are former K-12 science teachers and some of them have been TA or instructors of SMCs. This latter experience was most relevant for them since it was closer to the task of designing a SMC. These experiences provided them with contents, sequence of topics, activities, assessments, readings, or other resources they could use to design their own syllabus. Out of all the personal factors, experiences teaching SMC seem to be the most relevant factor that can be provided during their formal training in their doctoral programs, since this type of experience helps them to develop different dimensions of their PCK for teaching science teachers. Here they are exposed to the curriculum of these courses (knowledge of curriculum for teaching methods courses), the teaching strategies and activities implemented (knowledge of instructional strategies for teaching methods courses), and the assessment strategies to evaluate student teachers (knowledge of assessments in methods courses), and also the contents for this class (subject matter knowledge for science teaching). Unfortunately, 50% of participants have not had this formal learning/teaching experience provided in their doctoral programs. For this group, their K-12 teaching experiences were relevant. This situation is not very different of what has been found in the literature. Jablon (2002) found that only 34% of doctoral programs in science education required their graduates to participate in a mentored teaching of SMC. Other educators have reported drawing on their experiences teaching science to children when designing a SMCs (Smith, 2000).

A second relevant group of factors (theme) was their learning experiences, especially for those participants with little experience teaching science teachers. They recalled their learning experiences as elementary students (one participant in the elementary case), as student teachers, and as doctoral students. They considered these experiences for different purposes, like selecting contents, activities, and resources (readings) to include in their syllabi. For instance, they included activities that their instructors implemented with them in the past. Based on the purposes for what they were considering these learning experiences, it seems that these learnings helped them mostly to develop their “subject matter knowledge for science teaching”, that is, being familiar with the contents to include in a SMC, as well as their “knowledge of instructional strategies for teaching methods courses,” since they included instructional activities that their instructors implemented with them.

A third common factor across the three cases was the PSTEs’ research experiences. In the three cases, there were participants who included topics and readings related to their research in their syllabi. Since their research areas focus on science teacher education, they considered that their research topics were relevant to be included in their SMC syllabi. This suggests that their research experiences are contributing to the development of their “subject matter knowledge for science teaching,” since they are learning through their research about topics that are relevant for teachers to learn in the context of a SMC.

According to the findings of this study, it seems that multiple factors are helping PSTEs to develop different dimensions of their PCK for teaching science teachers, which is relevant for them during their pedagogical decision-making process when they are designing SMCs. One dimension that seems to be receiving less attention throughout their education, teaching, and research experiences is “knowledge of teachers' understanding of science and science teaching.” Only one participant in the secondary case considered teachers’ understanding or conceptions during the design of the SMC syllabus. This participant included a topic in his/her syllabus because it is challenging for teachers to understand and to teach it. The fact that only one participant considered this suggests a lack of attention to science teachers’ conceptions in doctoral programs. PSTEs should be provided with formal opportunities to learn about teachers’ conceptions of science, conceptions about science, and conceptions about teaching science. Developing their “knowledge of teachers' understanding of science and science teaching” will help them to make more informed decisions when they are educating future science teachers.

Based on the findings of this study regarding the PDM factors identified in the three cases, I am proposing a working framework (**Figure 19**) based on Henze and Barendsen (2019). I propose distinctive phases in this framework: the design of SMCs and the implementation of these courses, which will be followed by an evaluation phase. Each phase will have particular challenges, and particular personal and extra-personal factors influencing the PDM. Although, it is expected that many of the personal factors are the same during the design process (long-term PDM) and during the implementation (short-term PDM) of the SMC. But since this study did not explore the challenges and factors during the implementation of SMCs, this model requires further elaboration, specifically in terms of identifying personal and extra-personal factors influencing novice STEs' PDM process during the implementation of their designed SMCs.

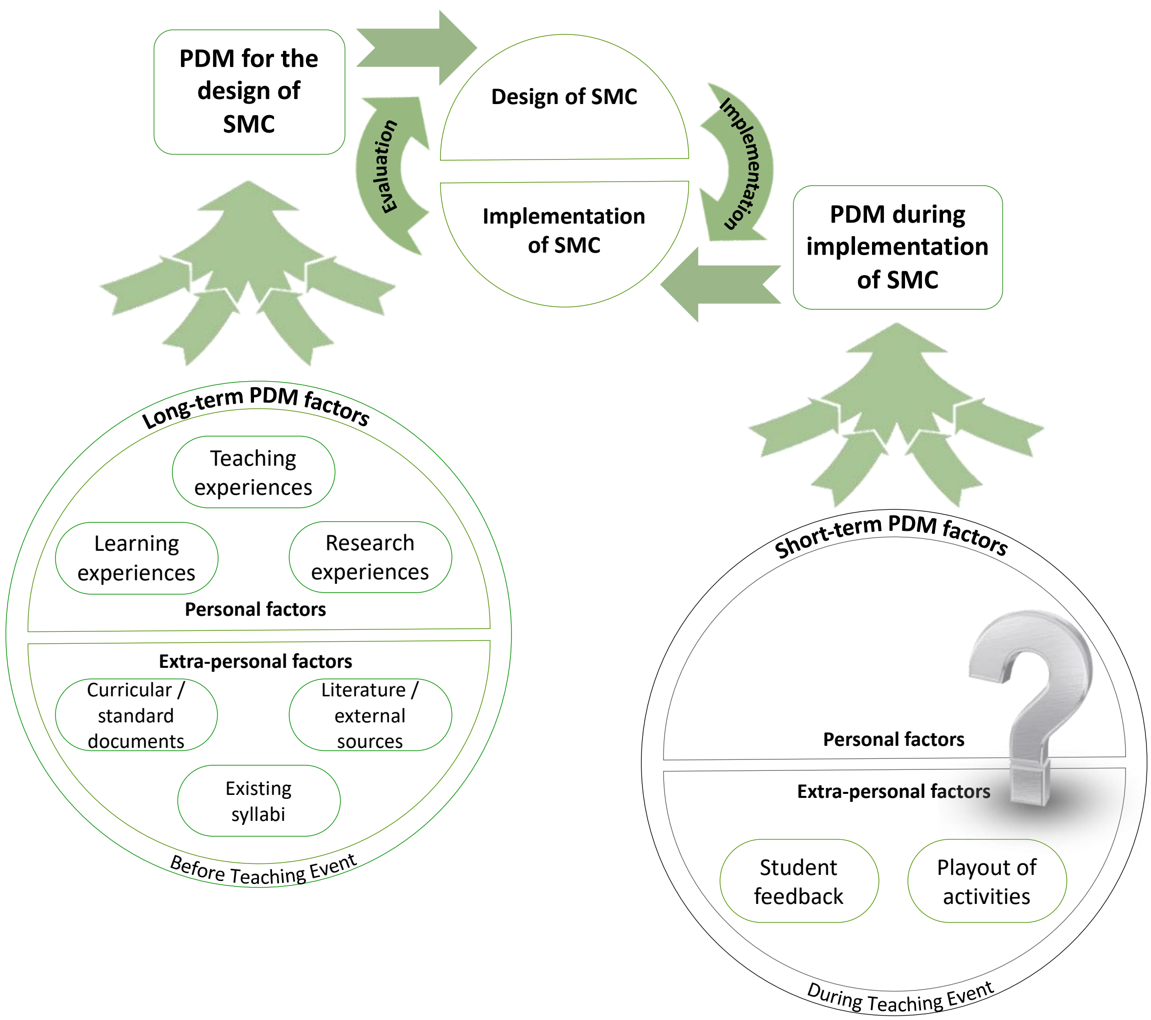

Figure 19. Framework depicting the design, implementation, and evaluation of SMC, and the personal and extra-personal factors influencing long-term and short-term PDM process.
(*SMC: science methods course, PDM: pedagogical decision-making*).

Implications and recommendations for practice

One of the findings of this study was that all the dimensions of the pentagon PCK model (Park & Oliver, 2008a) are being covered throughout the SCM syllabi in the three cases. This suggests that the PCK model is working as an implicit framework for the design of this class, similar to what has been found in the literature (Sickel & Witzig, 2017). Given that the main challenges identified in the three cases were related to the selection and organization of topics and the lack of an organizational framework, PSTEs could benefit from using PCK as an explicit framework for the design of these courses. According to Abell et al. (2010), "a key goal of your methods course, explicitly stated or implicit, is to help your methods students develop sufficient PCK for teaching science, to enable them to commence teaching science—what might be called a 'starter pack'" (p. 81) of PCK. Using PCK as an organizational framework during the course design process could contribute to achieving this goal.

Despite in the three cases participants covered all the PCK dimensions, there is a lack of emphasis on the KAs dimension (Knowledge of assessment of science learning). This could be suggesting a need for addressing the importance of including contents related to how specifically we asses students' science learnings. Doctoral programs could address this by developing science assessment courses for future STEs. In these courses, they could learn about the nuances of assessing scientific concepts, vs. beliefs about science, or how to assess science learning in a modeling context, vs. an argumentation context, or how to develop assessments for the NGSS, among many other topics related to the specifics of assessing students' science learnings.

According to the findings of this study, one of the biggest challenges identified in the three cases was the lack of an organizational framework for selecting and sequencing topics in a SMC. As stated earlier, STEs designing or teaching SMC may benefit from making an explicit consideration of PCK dimensions as a framework for selecting and sequencing topics or for the design of units or modules in their SMC. While many relevant topics for future science teachers can be selected and sequenced using a PCK model as an organizational framework, many other important topics or aspects related to science teaching and learning may not be explicitly addressed in a PCK framework, like the emergent codes identified in this study (i.e., reflection, teaching component [microteaching, teaching demos], learning contexts, use of technology, etc.). Consequently, a PCK model used as an organizational framework in the design of SMC could be a good starting point to provide teachers with their "starter pack" to commence teaching science (Abell et al., 2010), but not the only framework. Experienced researchers and science educators have explicitly used PCK construct to map the design of their science methods courses (Smith, 2000).

A second challenge identified for the elementary and secondary cases was designing assessments/rubrics for this class. They struggled with different aspects of planning assessments for teachers in the context of this class. This could be suggesting a need to develop STEs' knowledge of assessment in methods courses, one of the dimensions in the PCK model for science educators (Abell et al., 2009). As I suggested earlier, this could be addressed by offering science assessment courses for future STEs where they can not only develop their knowledge of assessment of science learning (KAs), but also their knowledge of assessment in methods courses to design strategies and tools to assess science teachers.

Regarding the factors influencing PSTEs' pedagogical decision-making process when designing their SMC, the most relevant extra-personal factor identified across cases was existing SMC syllabi from other instructors. They used these syllabi to define the goals, contents, and sequence of their SMC, for selecting and designing activities, assignments, resources, and teaching strategies. These documents provided them with multiple resources required for the design of SMCs. Similarly, their teaching experiences were a relevant personal factor in the design of SMCs. More specifically, their experiences as TA or instructors of SMCs. Out of all the personal factors, experiences teaching SMC seem to be the most relevant factor that can be provided during their formal training in their doctoral programs, since this type of experience helps them to develop different dimensions of their PCK for teaching science teachers. Professor offering these teaching internships can tailor these experiences to help PSTEs to develop their PCK for teaching science teachers, and address some of the challenges they face when designing SMCs. In this regard, researchers have advocated the inclusion of goals in doctoral programs to help graduate students to become STEs and be able to work as independent instructors of science teachers (Abell et al., 2009). Unfortunately, in a review of the curriculum of doctoral programs in science education, only 34% of these programs requires involvement in teaching SMCs, or mentoring pre-service or in-service teachers (Jablon, 2002).

Given the relevant role of PCK in science pedagogy, science teacher preparation, and SMCs, it is crucial to provide PSTEs with opportunities to develop their PCK for teaching science teachers. STEs have different backgrounds, experiences and they pursue different paths to become STEs (i.e., a doctorate in science education, in curriculum and instruction or curricular studies with an emphasis in science, doctorate in a science content area, among others). But independently of their background or the path they followed to become a STE, those who are going to educate future science teachers could benefit from developing their PCK for teaching science teachers. This could help them to overcome some of the challenges identified in this study. I recognize three approaches that could help with this task. (1) One approach could be to have this goal of developing teacher educators' PCK embedded in traditional doctoral courses. Although this may be challenging given the more research-oriented nature of doctoral courses, I think this goal could be more easily embedded in those doctoral courses more directly related to science teacher education. (2) A second approach could be to provide PSTEs with more opportunities for teaching science teachers. While not all the students in a doctoral program may be interested in preparing future science teachers, it would be beneficial to provide these opportunities for those who are highly interested in educating science teachers, either pre-service or in-service teachers, and either in formal or informal contexts. According to the results of this study, these experiences provided them with multiple resources required for the design of SMCs, and likely helped them to develop different dimensions of their PCK for teaching science teachers, so it is important to provide this opportunity to more PSTEs. (3) A third approach could be developing a more practitioner-oriented science teacher education course for those interested in educating science teachers, where they could learn about science teachers' conceptions and beliefs, search and design instructional resources to teach science teachers, and reflect on how their own research applies to practitioners or how science teachers could benefit from their research. The field of science teacher education has become more robust in the last couple of years and today we have a better understanding of teachers' conceptions and the challenges they present in the classroom. I think it would be beneficial for PSTEs to provide them with formal instances to discuss these conceptions and challenges.

Limitations and future research recommendations

Due to time constraints and the world pandemic situation, it was not possible to study participants' enacted practices in the context of a SMC. It would have been interesting to study how they implemented their SMC syllabus to see what other challenges they faced during this process as novice STEs, and what other factors are influencing their short-term pedagogical decision-making. These are decisions that STEs need to make on the spot during the implementation of a SMC. A few participants who have had experiences teaching SMCs mentioned that they have considered students' feedback on the design or re-design of their syllabus, in addition to how different teaching activities play out during the implementation. Having access to this context could have helped in identifying more implications for practice and could contribute to understanding better this understudied group of novice STEs.

Also, some of the challenges identified are related to the nature of the research design of this study. For instance, one challenge they mentioned is that they were unaware of the curriculum for other courses in the science teacher preparation program, so they did not know what topics were already studied by the student teachers. This made it hard for them to decide what topics they needed to cover in their SMC in order to avoid overlaps or prioritize some contents. Also, some of them mentioned that since they were unable to implement and test the syllabus, this made it hard for them to make time-management decisions. Because these challenges may be related to the nature and design of this study, they were not discussed in the findings of this study.

Future research should focus on studying different aspects related to the implementation of SMCs designed by novice STEs. For instance, it would be interesting to study short-term PDM factors influencing the implementation of the designed SMC syllabi, as well as new challenges that STEs face when they are teaching science methods to student teachers. This will contribute to having a more comprehensive view of the design-implementation-evaluation process of this key component of science teacher preparation programs, such as the SMCs.

It is also relevant to study how doctoral programs related to science education are preparing PSTEs to design and teach the science methods courses and science pedagogy courses in general. It would be beneficial for the scholars in this program to understand better how they can support their doctoral students for this task. The PCK model for teaching science teachers (Abell et al., 2009) could be a great tool to help scholars to recognize relevant dimensions where they need to support PSTEs. It would be interesting to study how the explicit consideration of this model as an organizational framework in doctoral programs could help PSTEs in developing their PCK for teaching science teachers. To address this in future research, it would be helpful to first characterize the curriculum of their doctoral programs. More specifically, it would be helpful to characterize the curriculum to which individual PSTEs were exposed to during their time in that program, since curricular requirements and courses offered by doctoral programs change over time, so not all graduates will take the same courses.

According to the findings of this study, the dimensions for the PCK model for educators that require more attention are (a) "knowledge of teachers' understanding of science and science teaching", (b) "knowledge of assessment in methods courses", and especially the (c) "curricular knowledge for teaching methods courses". Therefore, future research could also focus on understanding how an explicit emphasis on these dimensions in doctoral programs can improve PSTEs' planned and implemented practices for teaching science teachers. It is also important to be aware of the topics to which science teacher educators are not paying enough attention in their SMC syllabi, like the knowledge of assessment of science (KAs) identified in this study. Consequently, future research could study why this is happening and how this could be addressed by doctoral programs.

Finally, the data collected for this study could be organized and analyzed from different perspectives. For instance, participants could be organized in cases according to their K-12 science teaching experience, since participants in the study range from 0 to 18 years of K-12 teaching experience. The time they have spent teaching in a classroom setting could influence their views about what is important for science teachers, and consequently, this can influence the contents that they include in their SMC. Participants could also be organized in cases according to their experiences teaching SMCs. In this study, half of the participants have experience as a TA or instructor of SMCs, and the other half did not have these experiences. Since the main task in this study was to design a SMC for science teachers, having this experience can make a great difference in their PDM when deciding what contents to include. Similarly, the number of years in their Ph.D. could be another important factor influencing their PDM, so participants could also be arranged in cases based on this (i.e. doctoral students, doctoral candidates/ABD, close to graduation). And finally, since half of the participants were local and half of them were international, this could also influence the way they design their SMC, given the differences in curriculum standards (for instance, outside of the US it is common to have national standards) and teacher preparation programs.

More research on this topic could lead to generating guidelines for the preparation of science teacher educators, which could directly impact future science teachers around the globe.

Contributions

Contributions to the literature: The present study contributes to the gap identified in the literature. As stated earlier, there has been a lack of attention to the expertise and professional qualifications of the instructors of these courses (Lederman et al., 1997). Thus, it is necessary to understand better how science teacher educators are being prepared, and what experiences in their preparation or other experiences are affecting their decisions when designing SMC. This study contributes to identifying some of those factors and explains how some of these factors can be related to the dimensions of the PCK model for science educators. Additionally, this study identifies the range of dimensions/topics considered by PSTEs when designing SMC, which could help researchers to infer what topics are not receiving enough attention by STEs in the context of SMC, and this could lead to more research in those areas.

Theoretical/conceptual contributions: The findings of this study contribute to a better understanding of the factors influencing PSTEs' decisions when designing SMCs and a better understanding of the challenges faced by PSTEs during this process. This could contribute to elaborating on the different dimensions of the PCK model for science teacher educators proposed by Abell et al. (2009) by providing an understanding of the potential consequences of a lack of understanding of the different dimensions in this PCK model. An understanding of how some of the challenges that STEs face are related to some of these PCK dimensions could help to predict the consequences of shortcomings in the preparation they receive in doctoral programs in science education.

Practical contributions: The better understanding of the challenges that PSTEs face when designing SMC, and the factors that may be influencing their decisions, could be beneficial for doctoral programs preparing future STEs. Based on the findings of this study, the scholars in these programs can design specific strategies for supporting doctoral students in designing and implementing SMC, and to improve STEs' understandings of the different dimensions of the PCK model for science educators, especially the three dimensions that were pointed in this study as the ones that require more attention ("curricular knowledge for teaching methods courses", "knowledge of assessment in methods courses" and "knowledge of teachers’ understanding of science and science teaching"). Additionally, this study identified "knowledge of assessment of science learning" as one of the dimensions of the pentagon PCK model that received less attention by PSTEs in their SMC syllabi. Being aware of the topics that PSTEs are not emphasizing in SMC could help the scholars in doctoral programs to support PSTEs in those topics that may require more attention.

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Appendices

Appendix A: Rubric for coding the information from the syllabi (codebook)

(1. Carlson & Daehler, 2019; 2. Gess-Newsome, 2015; 3. Park & Oliver, 2008b; 4. Schneider, 2015)

	Codes	Descriptions[1, 2, 3, 4]
PCK	*OTS: Orientation to teaching science*	Refers to ideas about: • nature of learning and teaching science • purpose and goals of teaching science at different grade levels. It serves as a framework for instructional decisions. Some examples of frameworks are: process, academic rigor, didactic, conceptual change, activity-driven, discovery, project-based science, inquiry, and guided inquiry. Any explicit reference or activities for reflecting or eliciting these teachers' ideas was considered.
	KISR: Knowledge of instructional strategies for teaching science	Refers to ideas about • subject-specific strategies (general approaches to teach science, such as learning-cycles, conceptual change strategies, inquiry-oriented instruction) and • topic-specific strategies (more specific strategies to teach a particular topic within a subject) Any explicit reference to teaching strategies that are being taught or discussed was considered. Teaching strategies that are intended to deliver the course curriculum are excluded.
	KAs: Knowledge of assessment of science learning	Refers to ideas about • assessment of science learning ○ what dimensions of science learning are important to assess ○ what assessment methods and when to use ○ how student thinking is made visible or supported Any explicit reference to the teaching of different assessment strategies for science learning was included.

	KSC: Knowledge of science curriculum	Refers to ideas about • scope of science (identification of core concepts that are worth learning) • standards • curricular resources available for teaching particular subject • sequence of science • both the horizontal and vertical curricula for a subject. Any explicit reference to study, teach, or discuss these ideas was included.
	KSU: Knowledge of students' understanding in science	Refers to ideas about • students' initial science ideas and experiences • development of science ideas • how students express science ideas (i.e. demonstration of understanding, questions, and responses) • learning difficulties or challenging science ideas for students (and why they are challenging) • appropriate level of science understanding • motivation and interest in a topic • learning styles Any explicit reference to specific students' science preconceptions or misconceptions, or how teachers could identify these misconceptions was included.
Professional Knowledge Bases of RCM	*CK: Content Knowledge*	Refers to the academic content of a discipline (biology, chemistry, physics). It includes • discipline-specific knowledge and skills (i.e. nature of science or how to write scientific explanations), and • the relationship among domains, along with related topics and concepts within a domain • assessment and curriculum aspects of specific science contents were included in Knowledge of assessment of science learning (KAs) and Knowledge of science curriculum (KSC) (i.e. assessment of nature of science, nature of science in the NGSS, etc.)
	PK: Pedagogical knowledge	Refers to ideas about • strategies for classroom management • strategies for student engagement Examples: o engage students in collaborative learning o questioning techniques o differentiated instruction (ex. special needs, second-language learners) lesson plan design

	KS: Knowledge of students	Refers to ideas about • student cognitive and physical development • understanding student differences
	CuK: Curricular knowledge	Refers to ideas about • goals of a curriculum • curriculum structures • how to sequence lessons • role of a scope and sequence
	AK: Assessment knowledge	Refers to ideas about • design and use of formative and summative assessments • how to use results from those assessments to design or modify instruction
Emergent codes	*Other*	

Appendix B: Table for analysis of topics/dimensions in elementary science methods syllabus.

			Subunit / Participant 1 (EL)	Subunit / Participant 2 (CS)	Subunit / Participant 3 (ZG)	Subunit / Participant 4 (EM)

Pedagogical Content Knowledge	OTS: Orientation to teaching science	Topic(s) (section [i.e. course description, goals, schedule, etc.] / #weeks [if it's in schedule])	- Goals (**activity-centered** or **project-centered** classroom) - Schedule (constructivist earth science/3 weeks; **constructivist** life science / 4 weeks; constructivist physical science / 4 weeks)	- Course description (This course is intended to provide you with opportunities to **construct** a vision of what elementary science teaching and learning can be like; Building on current **research** on science teaching and learning; common **learning theories in science** education) - Schedule (Learning Theories / 1 week) - Schedule (Modeling in Elementary Science / 1 week)	- Goals (Develop habits of mind of science (openness, curiosity, and skepticism)	- Course description (the course will foster awareness in teacher candidates of the need to purposefully include **research-based strategies**; The epistemology of constructivism will be used to develop understanding of how and what students learn.) - Objectives (i.Pedagogical knowledge reflecting **current research** on how students **learn science**; Issues in teaching and **learning science in the elementary classroom** from **cognitive, social, and cultural perspectives**)

	KISR: Knowledge of instructional strategies for teaching science	Topic(s) (section / weeks)	- Objectives (designing teaching-learning activities, **science inquiry**)	- Objectives (It is your responsibility to learn how to negotiate your classroom environment and determine which **instructional strategies** meet your needs and goals) - Schedule (**Modeling** in Elementary Science / 1 week)	- Schedule (**Instructional strategies**: **Lectures, discussions, demos** / 1 week; Instructional strategies: **Inquiry** / 1 week; **Labs and laboratory safety** / 1 week)	- Objectives (develop a repertoire of **science-specific pedagogical strategies**) - Schedule (Module 1: Science Teaching Practices (relevance, standards, **inquiry vs. hands-on**)/ 1 week; Module 3: Developing Science Content (cooperative/ collaborative groupings & CER; elements of inquiry) / 1 week) (**Safety; disposal; living organisms**) / 2 weeks)
	KAs: Knowledge of assessment of science learning	Topic(s) (section / weeks)	- Goals (assess learning with understanding) - Objectives (elicit students' ideas about science)			- Assessments (● FEAPs Assignment: **Alternative Conceptions** Lesson Plan [75 points] ○ Observe class in practicum. ○ **Develop questions** to identify misconceptions)

	KSC: Knowledge of science curriculum	Topic(s) (section / weeks)	- Goals (**integration of science across the curriculum**, resources for early childhood science) - Objectives (**curricular materials appropriate for early childhood science**) - Course materials (NGSS, Georgia Performance Standards) - Schedule (**Georgia Performance Standards and the NGSS** / 1 week)	- Course description (the three-dimensional **Next Generation Science Standards**; professional resources for teacher learning, curriculum, and pedagogy) - Schedule (**Professional Resources Scavenger Hunt** / 1 week; **NGSS** eBook+ Objective 1 & Case Reading / 1 week; NGSS eBook+ Objective 2 and 3 / 1 week)	- Goals (6. **Leave the class with resources** (physical, cognitive, and connective) that will assist in teaching science in the future; 8. Gain knowledge and confidence in using **science standards** & science process skills as appropriate to grades PreK-12 and special education). - Schedule (**Science standards** in the classroom / 1 week; The science curriculum / 1 week)	- Course description (we will address issues such as: **interpretation of the standards** and their translation into meaningful teaching and learning activities, **integration across curriculum**) - Objectives (develop competence in planning and implementing K-6 science learning experiences consistent with... the mandates of **Florida's Next Generation Sunshine States Standards**) - Schedule (Module 1: Science Teaching Practices (relevance, standards, inquiry vs. hands-on) (Elements, models, manipulatives, science equipment) / 2 weeks)

	KSU: Knowledge of students' understanding in science	Topic(s) (section / weeks)	---	- Objectives (You need to consider the **backgrounds and experiences your students** bring to your classroom, and you need to be thoughtful about the experiences you provide and how these experiences support students' understandings of science; The complexity is due to the interplay between your understanding of science, your **students' understandings of science**, and your ability to orchestrate science learning experiences in your classroom)		- Assessments (● FEAPs Assignment: Alternative Conceptions Lesson Plan [75 points] ○ Observe class in practicum. ○ Develop questions to **identify misconceptions**. ○ Administer questions and analyze responses) - Schedule (Module 3: Developing Science Content (**Questioning & Misconceptions--** discrepant events / 1 week)

Professional Knowledge Bases (from RCM)	CK: Content Knowledge	Topic(s) (section / weeks)	- Goals (**nature of science and scientific knowledge**) - Objectives (**science processes skills, integrate science with other content areas**) - Schedule (**earth science** / 2 weeks; **life science** / 4 weeks; **physical science** / 4 weeks)	- Description (contemporary topics such as **engineering, sustainability**, and modeling) - Schedule (Children's Engineering / 1 week; **Socio-Scientific Issues** / 1 week, Exploring **Citizen Science** / 1 week)	- Goals (Understand the **relationship between science, society, and technology** (i.e., how does one impact the other)) - Assignments (Interactive Science Notebook (Book of Science/BoS). The goals of the ISN are: enhance the learning experience by increasing conceptual understanding of science content) - Schedule (**What is science**? / 1 week) - Schedule (Science content – **Physical Science** / 1 week; Science content – **Life Science** / 1 week; Science content – **Earth and Space Science** / 1 week; Science content – **Crosscutting concepts** and connections / 1 week; Science	- Course description (This competence involves a level of **understanding of the subject matter**, basic principles and processes underlying the **nature of science** along with its **historical and socio-cultural construction**; we will explore the following proficiencies: 1) Conceptual knowledge and understanding in science, 2) Abilities to participate in **scientific inquiry** and 3) Understanding the **nature of science and scientific inquiry**; You will be expected to demonstrate knowledge of core **science content knowledge relevant to the Sunshine State Standard**s... Hence, a variety of science topics

					content – **Engineering, technology** and the application of science / 1 week; **Socioscientific Issues** in the classroom / 1 week)	will form the context for each lesson. Some science content knowledge will be selected based on its difficulty for learners, and others will be selected because of their relatedness to the existing public schools' curriculum; we will explore how best to achieve **integration of STEM content and practices**, in addition to **other content areas**, for you to become more effective and confident elementary science teachers) - Objectives (develop competence in planning and implementing K-6 science learning experiences consistent with current research regarding the **nature of science**; i.Science

						conceptual knowledge and understanding)

	PK: Pedagogical Knowledge	Topic(s) (section / weeks)	- Goals (**culturally relevant science teaching** and learning) - Objectives (**multicultural dimensions** of the classroom, science for all) - Assignments (**lesson plan**)	- Course description (**diversity, equity, and cultural relevance in science teaching**) - Schedule (**Culturally Relevant Science** / 1 week)	- Goals (We'll us the revised **Bloom's taxonomy** to support **critical thinking skills** and develop scientific habits of mind) - Assignments (Final Exam: The final exam is comprehensive and multi-part. For the first part of the final exam, you will be writing a full **lesson plan** based upon the activity you chose and feedback that you received for your teaching demo.) - Schedule (**Planning** and assessing science teaching / 1 week) - Schedule (**Differentiated instruction** / 1 week)	- Course description (the course will foster awareness in teacher candidates of the need to purposefully include research-based strategies to encourage the **diverse range of learners, including gifted, ESE and ELLs**, in developing an appreciation and understanding for science; **science in the inclusive classroom**) - Objectives (develop competence in **planning** and implementing K-6 science learning experiences; •develop a repertoire of science-specific pedagogical strategies **appropriate for all learners, including gifted, ESE, and ELLs, in the inclusive classroom**; the role of the elementary school teacher

						in preparing appropriate activities for all students to learn science) - Course Requirements (II. ESOL Standards and Performance Indicators) - Assignments (● FEAPs Assignment: Alternative Conceptions **Lesson Plan** [75 points] ○ Develop a lesson plan targeting alternative conceptions that will be appropriate for all learners, including gifted, ESE, and ELLs. ●Lesson Plan [150 points] ○ You will create a one-day lesson based on a Florida NGSSS K-5 science benchmark. ○ Throughout the course, you will revise the lesson plan based on the new information you have learned. This includes how to develop

						science content, accounting for varying cognitive (ESE) and linguistic (ELL and WIDA standards) and sociocultural (CRP) abilities, assessments, etc.) - Schedule (Module 5: Teaching for your **students'** cognitive ability--**Differentiated Instruction** (Mastery level, rigorous vs. dumb-down, learning centers) (ESE, Choice & Variety in Assessments/questions) / 2 week) (Module 7: **Managing the Science Classroom** (Informal Learning; field trips; guest speakers)

	KS: Knowledge of Students	Topic(s) (section / weeks)	---			- Course description (According to **Piaget's stages of cognitive development**, elementary school children are undergoing dramatic **physical, mental, and emotional** growth. They are constructing knowledge about their world in both formal and informal learning environments. You will need to develop skills in listening to and understanding children as they experience science) - Schedule (Module 5: Teaching for your **students' cognitive ability--Differentiated Instruction** (Mastery level, rigorous vs. dumb-down, learning centers) (ESE, Choice & Variety in

						Assessments/questions) / 2 week)
	CuK: Curricul	Topic(s) (section / weeks)	---			
	AK: Assessment Knowledge	Topic(s) (section / weeks)	---			- Schedue (Module 2: **Assessment & Evaluation (formative & summative, diagnostic, achievement vs growth)** / 1 week)

Emergent codes	Other	Topic(s) (section / weeks)	*Reflection* - Goals (becoming a ref1ective practitioner and learner) - Objectives (reflect upon your own science teaching beliefs and practices) - Assignments (reflection modules / 9 weeks)	*Reflection & critical thinking* - Objectives (A primary goal of the course is to help you become a teacher who is thoughtful and critical... To be an effective science teacher, you need to evaluate your own understanding of science as well as be clear about your science learning goals for your students)	*Reflection* - Assignments (Interactive Science Notebook (Book of Science/BoS) The goals of the ISN are: •allow for reflection of learning opportunities; Homework/Quizzes/Daily Assignments: These assignments are intended to promote reflection as both a scientifically literate citizen and future teacher; Final Exam: ...there will be a written reflective component that describes changes that you made to the lesson pertaining to the feedback that you received. You will also be including a written science teaching philosophy statement.)	*Reflection* - Assignments (● STEAM Teaching [50 points] ○ Based on your participation in the Science and Math Night you will reflect and answer questions focusing on student/parent interaction and engagement which includes diverse learners of gifted, ESE, and ELLs.)

			Social justice in science - Goals (females and minorities in science)	*Diversity & Equity* - Course description (diversity, equity, and cultural relevance in science teaching) - Schedule (Diversity and Equity / 1 week)		*Culturally Responsive Teaching* - Schedule (Module 6: Teaching for your students' sociocultural identity--Culturally Responsive Teaching or CRP (Stance, social justice, own bias, marginalized groups) (Relevance/relationships; ELLs; "strategies") / 2 weeks)
			Learning contexts - Goals (outdoor learning environments) - Objectives (outdoor learning environment as a context for science teaching)		*Learning contexts* - Schedule (Science learning environment / 1 week)	

					Microteaching / teaching demo - Assignments (Course Project: Activity Binder and Teaching Demo: ... you will be leading a 20-25 minute class segment using one of these activities. Part of the grade for the teaching demo includes your attendance and participation for others' demo) - Schedule (Teaching Demos / 4 weeks)	*Teaching component* - Assignments (FEAPs Assignment: Alternative Conceptions Lesson Plan [75 points] ○Teach the lesson plan and have mentor teach sign evaluation ○ A rubric will be provided on Canvas and in class. ● Practicum Activity [50 points] ○ You will partake in developing a science night activity for students and parents to engage in. It will account for the sociocultural and linguistic diversity of the ELL students and parents, as well as those with exceptional learning needs (ESE).) *Microteaching / teaching demo* - Assignments (●

						STEAM Teaching [50 points] ○ With group, develop a STEAM lesson using either science or engineering practices, which will account for varying cognitive abilities (ESE). ○ Each group will teach one of our learning goals for the day by leading groups through the lesson. ○ Varying due dates; Groups will sign up for topic and day.)
			Teachers' effectiveness - Objectives (use theory to improve their teaching effectiveness)			*Effective science teaching* - Objectives (Elements of effective science instruction)

					Use of technology - Schedule (Educational technology in the science classroom / 1 week)	*Use of technology* - Schedule (Module 8: Technology, Tools, & Measurement (tech integration, equip--therm, scale, cylinder; Metric) / 1 week)
			Sustainability and environmental ed - Goals (water resources, sustainable ed practices in early childhood)	- Schedule (Sustainable Sourcing)	*Habits of mind of science* - Goals (Develop habits of mind of science (openness, curiosity, and skepticism))	*Confidence towards teaching science* - Objectives (develop positive attitudes and confidence toward science teaching in the elementary classroom)
				Teachers' identity - Course description (we will explore: teacher identity and voice as related to doing and teaching science) - Schedule (Introduction and Science Identity / 1 week)		*Observation* - Course description (Observations of teaching and learning in elementary classrooms and regular discussions with your colleagues will provide the forum for thinking about alternative ways of creating learning opportunities for your future students.)

				Interdisciplinary Teaching - Schedule (Module 4 Interdisciplinary Teaching (Reading, Social Science, & art) (Math, music, & P.E.) / 2 weeks)		
Emphasis reported by participants						
Other observed emphasis						

Appendix C: Table for analysis of topics/dimensions in middle-school science methods syllabus.

			Subunit / Participant 1 (HS)	Subunit / Participant 2 (HO)	Subunit / Participant 3 (KF)
Pedagogical Content Knowledge	OTS: Orientation to teaching science	Topic(s) (section [i.e. course description, goals, schedule, etc.] / #weeks [if it's in schedule])	- Outcomes (Develop an understanding of **reform-based** trends in science education policy and goals) - Activities (The 'Fish is fish' (Morrell & Popejoy, 2014) activity will introduce PSTs to **constructivism** and using **conceptual change** wherein they will look at their own conceptions, expose these conceptions to meaning making in new experiences, and accordingly revise or replace them.) - Schedule (Science as a discipline: Nature of science Scientific literacy Constructivism/ Conceptual change / 2 weeks)		- Assignments (Students will construct two written assignments, a "Personal Vision"...)

	KISR: Knowledge of instructional strategies for teaching science	Topic(s) (section / weeks)	- Outcomes (Develop an understanding of diversity of **teaching strategies** available for teaching science) - Schedule (**Teaching strategies**: **Ambitious Science Teaching, Investigation with data, Data representation/ graphing**, Differentiated instruction / 5 weeks) - Activities (card sort activity (Friedrichsen & Dana, 2003). The activity involves students reflecting on **20 different science teaching activities**, which are printed on cards. Each card reflects a different scenario; **Modeling subject specific strategies** in earth science: This activity brings into focus how teaching methods may be different in different science subjects. **Modelling in earth and space science** may be different from that in biology or physics; **Modeling**		- Schedule (Class Activities: **Hands-On verse Direct Instruction** / 1 week)

			subject specific strategies in physics while studying Newton's laws of motion; An activity that will not go as per plan: This will help them experience that all lessons do not go as per plan and may need **creativity and problem solving**. This can be done by leaving out an essential component of the experiment, not providing enough material for all students, use faulty equipment, or give different instructions to different groups (Baumgartner, 2010)) ***Safety*** - Outcomes (Ability to institute rules and procedures to ensure physical safety of students) - Schedule (**safety**) - Activities (Flinn scientific certification (PSTs will complete the Flinn Scientific **Safety Certification** online on their own time), **Science**		

			classroom safety court cases, Audit of lab/classroom for safety)		
	KAs: Knowledge of assessment of science learning	Topic(s) (section / weeks)	**Eliciting student prior knowledge** in electricity (Postlethwaite & Skinner, 2017) - Activities (**Quality questioning** (Gregerson, 2011) ... **Rubrics to evaluate inquiry** (Lunsford & Melear, 2004))		- Objectives (▶ Select, adapt, and construct **traditional assessment items** (multiple choice and constructed response) with the goal of achieving the best possible balance between authenticity, efficiency, validity, reliability, and fairness. ▶ Select, adapt, and construct **performance assessment tasks and rubrics** for evaluating students' proficiency in the processes of **scientific and engineering investigation**.

	KSC: Knowledge of science curriculum	Topic(s) (section / weeks)	- Schedule (Understanding the **standards-NGSS**: Introduction of NGSS Integrating the **three dimensions**/ 2 weeks) - Activities (Examining the **standards** (Brunsell, Kneser, & Niemi, 2014) **NGSS vocabulary** (Brunsell et al., 2014) **Structure of the NGSS** (Brunsell et al., 2014) **NGSS conceptual shifts** (Brunsell et al., 2014))		- Objectives (Develop **"curriculum triage"** skills, critically applying various criteria for the design of the specific **scope and sequence** of the Physical Science components of a **curriculum framework** for middle grades science, with reference to both **current state and local** objectives and currently influential U. S. national science standards documents: o ***Georgia Standards of Excellence (GSE)*** o *Clarke County School District GSE Curriculum Map* documents o *Next Generation Science Standards (NGSS)*) - Objectives (•**Select, adapt, and construct "3-Dimensional" science lessons, units, and projects**, incorporating and integrating Disciplinary Core Ideas, Scientific Practices, and

					Cross Cutting Concepts; •**Select, adapt, and construct several specific "hands-on, minds-on" activities** appropriate for middle school students in each of several major Earth and Life Science topic areas typically included in specifications of middle grades science objectives.)
	KSU: Knowledge of students' understanding in science	Topic(s) (section / weeks)	- Activities (The activity called "Where does all the mass come from?" (Haslam & Treagust, 1987) will exposes **student misconceptions** about photosynthesis)		- Objectives (• Understand the importance of recognizing major cognitive **scientific misconceptions** common among middle school students, and become familiar with specific examples in all major topic areas of **Physical Science**.)

Professional Knowledge Bases (from RCM)	CK: Content Knowledge	Topic(s) (section / weeks)	- Outcomes (Develop an understanding of science as a discipline) - Schedule (Science as a discipline: **Nature of science Scientific literacy** Constructivism/ Conceptual change / 2 weeks) - Activities (New Society' activity (Cavallo, 2008) will set up the class for an introduction to and discussion on **NOS**; Investigation into **photosynthesis**. Working with data (Witzig, 2017); Modeling subject specific strategies in physics while studying **Newton's laws of motion**; Teaching **graph literacy** (Zucker, Staudt, & Tinker, 2015); Teaching **thermal energy concepts infused with mathematics** (McHugh, Kelly, & Burghardt, 2017); **Engineering design** activity: PSTs will engage in an engineering design activity called 'Minute madness' (Morrell & Popejoy, 2014).	- Goals (This course is intended to encourage middle school science teacher candidates to construct a vision about **current topics on science**; develop an understanding about current **socio-scientific topics**; The main purpose of this course is to develop a scientific perspective to discuss **controversial topics** in science) - Topics (Example of socio-scientific topics for this course: **Pandemics, Vaccines, Fires, Water, Climate Change, GMOs, Robots, Renewable energy, Cancer research, Organ donation, Nanotechnology, Nutrition and diet research**) - Assignments (Weekly Response Papers: During the term, you should write five papers that include answering some questions like, "why is this topic essential?" "what are the benefits of working on this	- Objectives (• Develop personal proficiency in major scientific and engineering practices as enumerated in the NGSS, and select, adapt, and construct middle-grades-level activities appropriate for developing them; Develop personal proficiency in major scientific and engineering practices as enumerated in the NGSS; •Demonstrate an understanding of the Nature of Science as a distinctive way of knowing, and describe and apply selected aspects of the history of science and of current scientific research that can inform science teaching and curriculum) - Schedule (Class Activities: Continental Drift Activity / 1 week; Class Activities: Teaching Socio-Scientific Issues / 1 week)

			They will work in small groups to create a prototype of a timer that will measure 60 seconds accurately, using the given material)	topic for society?", "who are working on this topic?" "Why is this topic popular?" etc.) - Assignments (**Research Proposal**: At the end of the semester, you should an original research proposal. The topic would be the subjects we work on the class or a different one. Your research proposal should include a cover page, introduction, review of literature, aims and objectives, research design and methods, budget, timeline, reference list. It should be 3500-5000 words.)	

	PK: Pedagogical Knowledge	Topic(s) (section / weeks)	- Outcomes (Design instruction that is developmentally appropriate and cognizant to the needs, values and interests of a **varied group of students**) - Course format (**differentiating instruction**... will be embedded in classroom activities) - Schedule (Learning environment: **Classroom management**; Equity; Safety; Authentic science problems; Informal education) - Activities (Enact and discuss classroom scenarios <u>Equity in nutrition</u> (Dooley, 2000). Each group of PSTs will be given a **classroom management scenario**. They will work in groups to develop a script and enact the given scenarios)		- Assignments (**Lesson Plans**: Earth Science Lesson - 1) After observing 6th grade science classes for 6 weeks, students will **construct a science lesson** for an Earth Science standard not yet covered in the observations; 2) Life Science **Substitute Lesson Plan-** After observing 7th grade science classes for 6 weeks, students will **construct a lesson plan** for a **Life Science** standard not yet covered in the observations. This lesson should be written as if for a substitute) - Assignments (Final Exam: Students will construct two written assignments... a "**Classroom Management Plan**") - Objectives (•Identify and address examples of classroom and materials management issues of special importance for teaching science) - Schedule (Class Activities: How

					to **design science lesson plans** / 1 week; Class Activities: **Classroom & Lab Behavior Management** / 1 week)
	KS: Knowledge of Students	Topic(s) (section / weeks)			
	CuK: Curricular Knowledge	Topic(s) (section / weeks)			

	AK: Assessment Knowledge	Topic(s) (section / weeks)	- Outcomes (Create assessments that are consistent with teaching goals and methods and allow various ways of representing knowledge.) - Course format (diagnostic and formative assessment... will be embedded in classroom activities) - Schedule (**Formative assessment Summative assessment Differentiated assessment**/ 1 week) - Activities (**Quality questioning** (Gregerson, 2011) **Formative assessment** probes (Eberle & Keeley, 2008) **Differentiated assessment** (Bittel & Hernandez, 2006))		

Emergent codes	Other	Topic(s) (section / weeks)	*Reflection* - Outcomes (Understanding of reflection in science learning) - Course format (Classroom discussions will give PSTs opportunities to be reflective of their learning and experiences; PSTs will also write a reflective online journal each week) - Activities (card sort activity (Friedrichsen & Dana, 2003). The activity involves students reflecting on 20 different science teaching activities, which are printed on cards. Each card reflects a different scenario)		*Reflection* - Assignments (Weekly Reflections: Students will complete a brief reflection after each class session. If readings were assigned for the week, students will include a brief reflection on the specified reading in their response)

			Diversity and Equity issues - Activities (Lab on equity: PSTs will get opportunities to discuss and experience issues related **to equity in science education**) - Schedule (Learning environment: Classroom management; **Equity**; Safety; Authentic science problems; Informal education)		*Ethical, Cultural and Social Issues in Science Teaching* - Objectives (Ethical, Cultural and Social Issues in Science Teaching •Describe the problematic nature of several ethical, cultural, and social issues that commonly arise in middle school Life Science and Earth Science teaching, and some relevant legal, sociological and psychological principles that may help teachers, students and parents to resolve them: o Use and treatment of animals (living and dead) in the science classroom o Interactions between science and religion, especially in regard to teaching the subject matter areas of cosmology, historical geology, and biological evolution)

			Learning environments - Schedule (**Learning environment**: Classroom management; Equity; Safety; Authentic science problems; Informal education)	*Learning environments* (create a rich learning environment in classrooms to discuss “hot-topics” in science)	*Microteaching / teaching demo* - Schedule (Class Activities: Content demo activity/ 6 weeks)
					Use of technology - Objectives (Use of Electronic Technologies in Science Teaching • Describe examples of the advantages and limitations, as teaching tools for middle school science, of: o selective, creative, and interactive use of video footage o other internet-based resources, e. g., scientific information databases and collaborative "citizen science" projects)

					Observation - Assignments (Observation Journal: While observing the four unique classroom environments, students will complete an observation journal. This should include general observations including questions, positive, and constructive comments on the teaching methods) - Schedule (Observations: 6th Grade Classes / 6 weeks; Observations: 7th Grade Classes / 6 weeks)

			- Schedule (Learning environment: Classroom management; Equity; Safety; Authentic science problems; **Informal education**)		*Research* - Assignments (Inquiry Project (Graduate Students Only): Graduate students will determine a research question or problem to investigate during the course. Students can use observations, including field notes, as data sources. Students will need to complete a short write up including the problem/question, a rationale, data and analysis, and conclusions.)
			Out of field instruction - Course format (The course will provide opportunities to PSTs to... create a unit plan in an OOF subject)		*Science fair* - Schedule (Class Activities: How to do Science Fair with your students / 1 week)
Emphasis reported by participants					
Other observed emphasis					

Appendix D: Table for analysis of topics/dimensions in secondary science methods syllabus.

			Subunit / Participant 1 (AF)	Subunit / Participant 2 (HT)	Subunit / Participant 3 (YH)
Pedagogical Content Knowledge	OTS: Orientation to teaching science	Topic(s) (section [i.e. course description, goals, schedule, etc.] / #weeks [if it's in schedule])	- Course description (ability to translate the **theories of science education** into classroom practice; **research-based teaching** methods/strategies) - Course objectives (Build a repertoire of science teaching and learning knowledge; Demonstrate proficiency with identifying the essential features of **inquiry-based and phenomena-based science teaching**) - Schedule (**Phenomena-based Science Teaching**/ 1 week)	- Goals (How can teachers help students to become **independent active learners**? / What "tools" can assist students in becoming an independent active learner?) - Purposes (promote your students to be independent active learners)	

	KISR: Knowledge of instructional strategies for teaching science	Topic(s) (section / weeks)	- Course objectives (Create lessons that demonstrate the effective application of important ideas and skills, including **scientific inquiry** and reasoning) - Schedule (**Laboratory Activities in Science**)	- Course description (Deciding which **instructional approach** should be used requires you to be artful in realizing what kind of **learning needs** to happen) - Goals (What factors do teachers need to consider when deciding on **instructional approach**?) - Purpose (become familiar with factors that influence learning, such as... **knowledge, teaching approaches**; develop the ability to choose **appropriate instructional approach**) - Assignments (Compare and contrast **different instructional approaches** (advantages / disadvantages, when to use)) - Schedule (Instructional approaches / 2 week)	- Goals (The primary goal of this course is to equip preservice teachers with enough knowledge with **physics teaching methods**; 1) Know the **different teaching methods of physics**) - Schedule (Know the common methods used in physics teaching (**inquiry-based** learning etc.)/ 1 week; Know the basic process of **teaching physics experiments** / schedule)
	KAs: Knowledge of assessment of	Topic(s) (section / weeks)			

	KSC: Knowledge of science curriculum	Topic(s) (section / weeks)	- Course description (including curriculum design aligned with the **NGSS**) - Course bibliography (American Association for the Advancement of Science. (1993). **Benchmarks for science literacy**. New York: Oxford; National Research Council. (1996). **National science education standards**. Washington: National Academy; Olson, S. & Loucks-Horsley, S. (Eds.). (2000). Inquiry and the national science education standards: A guide for teaching and learning. Washington, DC: National Academy Press.)	- Goals (What **resources are available for beginning secondary science teachers**?) - Schedule (Secondary science curriculum and **state/national science education standards**)	- Goals (**Design a physics content** course for students; Design a **physics lab** course for students) - Assignments (**design physics teaching instruments**: this course offers you a chance to design a physics teaching instrument to help you demonstrate the experiments. You should select any physics topics (such as the conversation of energy), and construct a demonstrative instrument) - Schedule (Have a basic understanding of **national standards**; Know the basic process of teaching physics, and how to find **resources in physics teaching** / 1 week) - Schedule (Present the instrument / 3 weeks)

	KSU: Knowledge of students' understanding in science	Topic(s) (section / weeks)	- Schedule (**Misconceptions**)	- Course description (recognizing the **amount of existing knowledge** the students have) - Purpose (become familiar with factors that influence learning, such as ... **students' background knowledge**)	

Professional Knowledge Bases (from RCM)	CK: Content Knowledge	Topic(s) (section / weeks)	- Course description (**integrating other subject matter areas with science**) - Course objectives (Develop an understanding of **how science works**) - Course assignments (Science & Teaching Paper You will write a paper to discuss your **ideas about how science works** and how you will adopt **scientific thinking and reasoning** in your classroom. Your paper should include: (a) A clear definition of “science”, (b) Discussion about **how science works**, (c) Discussion about **scientific thinking and reasoning**, (d) Discussion about the **role of science in everyday life**, (e) Discussion about how the readings and other class activities has changed the way you view science...) - Schedule (**Nature of Science**/1 week; **Science and Engineering Practices**/ 1 week)	- Goals (What is the **nature of science and scientific knowledge**?) - Purpose (understand better the **nature of scientific knowledge** and be able to implement it in teaching content knowledge; become familiar with factors that influence learning, such as **type of knowledge** (epistemic knowledge, conceptual knowledge, procedural knowledge, etc.) - Schedule (The **nature of science** /1 week)	

	PK: Pedagogical Knowledge	Topic(s) (section / weeks)	- Course objectives (examining issues related to **teaching science for all students,** including **culturally responsive science teaching** and equality-equity issues related to science; Identify instructional approaches that facilitate **learning by students with special needs**) - Assignments (Developing a **Lesson/Unit Plan**: Work in groups of no more than two, develop a one-week science lesson/unit plan for a specific high school grade level...) - Schedule (**Equitable Science Teaching**/ 1 week; Curriculum and **Lesson Planning**/ 1 week)	- Assignments (Case studies about **classroom management**) - Schedule (**Classroom management** / 1 week; **lesson planning**/ 1 week)	- Assignments (**designing lessons**: You are required to design a 30-minute lesson plan at the mid-term. Instructors and part of your classmates will assess your lesson plan according to the rubric... You have nearly half semester to revise it according to the suggestions provided by the instructors and classmates) - Schedule (Share your **lesson plan** with your group members; discuss and revise it / 1 week)
	KS: Knowledge of Students	Topic(s) (section / weeks)			
	CuK: Curricular Knowledge	Topic(s) (section / weeks)			
	AK: Assessment Knowledge	Topic(s) (section / weeks)	- Course objectives (Learn about different **types of assessments** and **develop assessment items** to evaluate student learning) - Schedule (**Assessment**/ 1 week)	- Goals (How can teachers and students **assess learning** with understanding?) - Schedule (**Types of assessment** / 1 week)	- Schedule (Know **how to evaluate students' performance** / 1 week; Know the **basic principles of designing an exam** / 1 week)

Emergent codes	Other	Topic(s) (section / weeks)	*Reflection* - Course objectives (reflecting on the teaching and learning of high school science) - Assignments (Article Reflection: For this assignment, you will write an article reflection...)	*Reflection* - Purposes (reflect upon your teaching, and your peers' teaching) - Assignments (Reflection on self-regulated learning strategies)	
			Learning contexts - Schedule (Laboratory Activities in Science; outdoor science teaching)	*Learning contexts* - Goals (How to design an effective learning environment?) - Purpose (become familiar with factors that influence learning, such as... learning environment) - Schedule (Designing the learning environment/ 1 week)	
			- Course objectives (examining issues related to teaching science for all students, including culturally responsive science teaching and **equality-equity issues related to science)**	*Teaching practice / microteaching* - Goals (What do teachers do to prepare for teaching? What do teachers do when they teach science?) - Assignments (Micro-teaching) - Schedule (Micro-teaching / 3 weeks)	*Teaching practice / microteaching* - Assignments (you are required to teach a lesson in the class using the lesson plan you designed. The instructor and the classmates will pretend to be the students) - Schedule (Practice Teaching / 4 weeks)

			Use of technology - Course description (using educational technologies to support science lessons)	*Self-regulated learning* - Assignments (Reflection on self-regulated learning strategies) - Schedule (Self-regulated learning strategies / 1 week)	*Physics teaching trends around the world* - Schedule (Know the popular trends in physics teaching around the world / 1 week)
Emphasis reported by participants					
Other observed emphasis					

Appendix E: Instruments

Background Survey

This survey asks you some basic information about your academic, professional, and personal background. All information you share here will be confidential. To ensure confidentiality, identifying information will be modified, replaced, or deleted for academic research or publication. This survey is NOT an evaluation of you. You will not be graded or judged based on your answers.

1. What is your name?

2. What is your undergraduate degree?

3. In what country did you get your undergraduate degree?

4. Have you ever participated in any professional development program?
A) Yes
B) No

If yes -->

4.1 Could you please list and describe the PD program(s) you have participated in during your teaching career?

5. Please, indicate any graduate degree(s) you have completed or are currently completing.

5.1 How far are you in your PhD program?
A. 1st year
B. 2nd year
C. 3rd year
D. 4th year
E. 5th year

F. 6th year and over

6. Have you ever taken an undergraduate science methods course?
A. Yes
B. No

If yes-->

6.1 Could you please indicate the name(s) of this(these) course(s) and the approximate year you took it(them)? Example: Science methods for middle school - 2010

7. Have you ever taken a graduate science methods course?
A. Yes
B. No

If yes-->

7.1 Could you please indicate the name(s) of this(these) course(s) and the approximate year you took it(them)? Example: Methods for science teaching - 2015

8. Have you ever been teaching assistant for a science methods course?
A. Yes
B. No

If yes-->

8.1 Could you please indicate the name(s) of this(these) course(s), the approximate year it(they) was(were) offered and the level of this(these) course(s)? Example: Elementary science methods - 2015 - Elementary

8.2 Could you please briefly describe the course(s) and your role in it?

9. Have you ever taught a science methods course as primary instructor?
A. Yes
B. No

If yes-->

9.1 Could you please indicate the name(s) of this(these) course(s), the approximate year it(they) was(were) offered and the level of this(these) course(s)? Example: Methods for science teaching - 2018 - Middle school

9.2 Could you please briefly describe the course(s)?

10. Are you affiliated with, or have you been affiliated with any scientific or educational associations? (professional or research associations)
A. Yes
B. No

If yes-->

10.1 Could you please list the associations you have been or are currently affiliated with?

11. How many years of teaching experience do you have in K-12 contexts?

11.1 In what country(countries) have you taught in K-12 contexts?

11.2 Please indicate the number of years of teaching experience you have in each of the following k-12 levels.

- ☐ year(s) of experience in kindergarten

☐ year(s) of experience in 1st grade
☐ year(s) of experience in 2nd grade
☐ year(s) of experience in 3rd grade
☐ year(s) of experience in 4th grade
☐ year(s) of experience in 5th grade
☐ year(s) of experience in 6th grade
☐ year(s) of experience in 7th grade
☐ year(s) of experience in 8th grade
☐ year(s) of experience in 9th grade
☐ year(s) of experience in 10th grade
☐ year(s) of experience in 11th grade
☐ year(s) of experience in 12th grade

11.3 What subjects are you teaching or have you taught in those levels?

kindergarten [ ]
1st grade [ ]
2nd grade [ ]
3rd grade [ ]
4th grade [ ]
5th grade [ ]
6th grade [ ]
7th grade [ ]
8th grade [ ]
9th grade [ ]
10th grade [ ]
11th grade [ ]
12th grade [ ]

12. Are you planning to be teaching assistant or primary instructor for a science methods course next semester?
A. Yes
B. No

12.1. What science methods course?

Thank you very much for your time devoted to answering this survey! This is going to be really helpful for my project. See you on the screen soon!

Interview protocol Science Methods Session

For starting with the design of your science method course, I would like to ask you to brainstorm on some general areas or topics you want to include in your course, and then please write them down. After that, please think in some more specific concepts related to the general topics and try to create a concept map for organizing the contents of your course.

During this process, I would like to ask you to do something called "think aloud." This is a process where you literally say everything that is on your mind as you are working on a task. The more you explain how you are thinking, the more helpful for the study is this task. Don't be concern about your pacing. I may sometimes interrupt with follow up questions.

The purpose is for me to learn about your process of developing a science methods course.

- What are you thinking?
- Is there any specific sequence you'd prefer to arrange these topics?
- Is there any other topic or dimension you'd like to add?
- Where did you hear about this topic? Why did you add this topic?
- What kind of assignments or assessments would you like to add?
- Where would you look for improving this outline?

Interview Protocol Reflection Session

Thank you very much for sharing your syllabus. I think you did a great job!

I would like to ask you to represent the process you followed for designing your science methods syllabus. You could create a type of roadmap for organizing your ideas. You can use the figures below to represent the stages or steps you followed.

After the action map:

0. Could you please explain your process map?
1. What was the most challenging part of designing a science methods syllabus?
2. How did you fix that?
3. Were there any other difficulties?
4. What was the easiest part of designing a science methods syllabus?
5. What resources did you use for designing your science methods syllabus?
6. How did you use those resources? For what purposes did you use those resources? (for searching topics examples, for searching assignment examples, for searching readings, etc.)

--> Did you use it for topics?

--> Did you use it for assessment?

--> Did you use it for readings?

7. Is there anything you would have done differently in this process?
8. What do you think is the heart of your science methods course? What is for you the central component of your syllabus?
9. After students finish your course, what is the take-home message you want them to remember? What is for you the most important take away they should keep?
10. Was there any important learning for you during this process?

Reflection paper

Please provide a reflection on the process of designing a science method course.

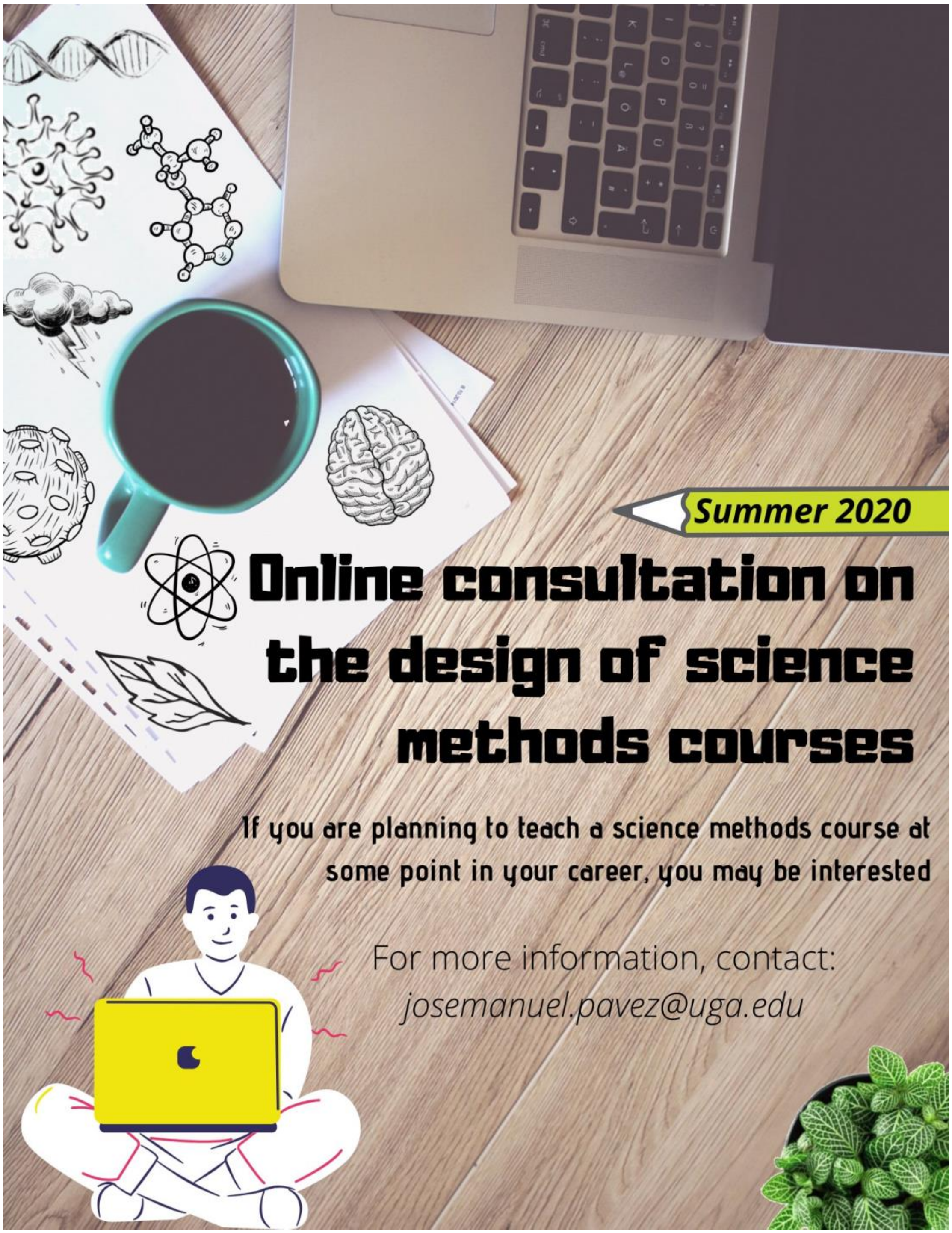
Please consider the following questions to guide your thoughts:

- What were some difficulties you faced when developing a science method course?
- How did you overcome those difficulties?
- What was something easy for you during the process?
- Was reflection helpful during the process? How was it helpful?
- What is for you the most relevant component of your science method course? Why is this important to you?
- What are some strengths of your science method course?
- What are some weaknesses of your science method course?
- How your science method course could be improved?
- What was something new you learned during this process?
- Do you think you could help others in the process of developing a science method course? How? Why?

Name:

Appendix F: Recruitment materials and emails

Recruitment Flyer



Recruitment Email

Subject: Invitation to create your science method course syllabus

Hello [NAME]

I am writing to you to invite you to participate on my dissertation study. If in the future you think you will be teaching a science method course, either at the elementary, middle or secondary level, you may be interested in working on this. Through the study, I will guide you in the design process of a science method course, the final product will be a syllabus for this class, which is a typical requirement from universities when you are applying for jobs in the science education field. So, your participation on this study would be a great opportunity for you to get you started with this task, no matter how far you are from starting your job applications.

Below I am providing more details about the study. If you are willing to participate, you will receive a printed copy of this information in the consent form.

Purpose of the Study
This study has three purposes: (1) to characterize the emphasis considered by prospective science teacher educators when designing a science method course; (2) Identify difficulties and needs prospective science teacher educators encounter when designing a science method course; (3) Identify potential factors influencing prospective science teacher educators' emphasis on their designed science method courses

Study Procedures
If you agree to participate, you will be asked to participate in a tutoring program that will take place in five individual 60-minutes sessions over a period of four months, according to your availability, starting in March 2020. During these sessions you will be guided through the process of developing a teaching philosophy statement and designing a science method course (syllabus). During this process, you will be provided with materials to help you with the tasks, and you will be asked to think out loud. Before the first session, you will be asked to complete a background questionnaire (5 minutes approx.) and during the fifth session you will be asked to participate in an interview (45-60 mins approx.) about the process of designing a method course. After the last session, you will be asked to write a 1-2 pages reflection paper (30 mins approx.).

Benefits
Your participation in this project could be beneficial in different ways. First, you will be provided with assistance and materials to guide you through the development of your teaching philosophy statement and the design of a science method course, two requirements for when you are applying for a job position. At the end of the sessions you will have an elaborated first version of both documents. Additionally, you will have the possibility of reflecting on your own process, identifying weaknesses and strengths on your documents, so it would be easier for you to improve these documents in the future when you need to

write the final version before applying for jobs. Also, since reflection is going to be an essential component during the sessions, you will learn about the process of designing a science method course, and this may help you with the development of other courses in the future.

Audio Recording
As part of the study, the tutoring sessions will be audio recorded, if the participant agree with that. Audio files will be saved in a password-protected computer, and after they are transcribed, they will be deleted. You may still participate in this study even if you are not willing to have the sessions or interview recorded.

Privacy/Confidentiality
No critical data such as personnel records (e.g., date of birth, contact information, SSN) will be collected during this study. All the participants will be associated with a pseudonym, and it will be used for the analysis of background questionnaire, teaching philosophy statement, draft of syllabus and reflection paper. This will allow to connect participants' responses from the different data sources. Within a period of 30 days after data is collected, all real names are going to be replaced in the oral and written data sources during the transcription and/or digitalization process. Any other identifying information will be modified, replaced, or deleted to avoid that someone can figure out participants' identity. All digital files (written documents, audio files) will be saved in a password-protected computer, and only researchers working in the project will have access to these documents. All files will be deleted after the analysis is complete at the conclusion of this project.

Do not hesitate to contact me if you have any questions about this, or if you want to meet me in person to talk about it. And please let me know if you are interested in participating in the study, I would really appreciate it.

Thank you!

José M. Pavez

Participant Consent Form

Study of the design process of a science method course by prospective science teacher educators

Researcher's Statement

We are asking you to take part in a research study. This form is designed to give you the information about the study so you can decide if you want to participate in the study. Please read the following information carefully and ask the researcher if there is anything that is not clear or if you need more information. This process is called "informed consent." Taking part in this study is completely voluntary. Even after agreeing to take part, you can opt-out at any time with no penalty or harm of any kind. A copy of this form will be given to you.

Principal Investigator	**Co-Investigator**
Julie Kittleson *Science and Mathematics Education* jkittl@uga.edu	Jose Pavez *Science and Mathematics Education* josemanuel.pavez@uga.edu

Purpose of the Study

This study has three purposes: (1) to characterize the emphasis considered by prospective science teacher educators when designing a science method course; (2) Identify difficulties and needs prospective science teacher educators encounter when designing a science method course; (3) Identify potential factors influencing prospective science teacher educators' emphasis on their designed science method courses

Study Procedures

If you agree to participate, you will be asked to participate in a consultation program that will take place in four individual 30 to 60 minutes sessions over a period of four months, according to your availability, starting in March 2020. During these sessions you will be guided through the process of developing a teaching philosophy statement and designing a science method course (syllabus). During this process, you will be provided with materials to help you with the tasks, and you will be asked to think aloud. Before the first session, you will be asked to complete a background questionnaire (5 minutes approx.) and in the last session you will be asked to participate in an interview (45-60 mins approx.) about the process of designing a science method course. After the last session, you will be asked to write a 1-2 pages reflection paper (30 mins approx.). Total estimated time would be 5 hours and 35 minutes over a period of 5 months.

The planned sessions are:

- 1st meeting: Crafting Teaching Philosophy Statement
- 2nd meeting: Brainstorming, outline of topics & assignments for science methods course
- 3rd meeting: Reflection on the design process and quality of science methods course
- 4th meeting: Interview

Risks and discomforts

There are no risks associated with this study.

Benefits

Your participation in this project could be beneficial in different ways. First, you will be provided with assistance and materials to guide you through the development of your teaching philosophy statement and the design of a science method course, two requirements for when you are applying for a job position. At the end of the sessions you will have an elaborated first version of both documents. Additionally, you will have the possibility of reflecting on your own process, identifying weaknesses and strengths on your documents, so it would be easier for you to improve these documents in the future when you need to write the final version before applying for jobs. Also, since reflection is going to be an essential component during the sessions, you will learn about the process of designing a science method course, and this may help you with the development of other courses in the future.

Audio Recording

As part of the study, the consultation sessions will be audio recorded, if the participant agree with that. Audio files will be saved in a password-protected computer, and after they are transcribed, they will be deleted. Please provide initials below if you agree with the sentences. You may still participate in this study even if you are not willing to have the sessions or interview recorded.

_______I am willing to have the interview recorded (audio only).

_______I am willing to have the consultation sessions recorded (audio only).

Privacy/Confidentiality

No critical data such as personnel records (e.g., date of birth, contact information, SSN) will be collected during this study. All the participants will be associated with a pseudonym, and it will be used for the analysis of background questionnaire, teaching philosophy statement, draft of syllabus and reflection paper. This will allow to connect participants' responses from the different data sources. Within a period of 30 days after data is collected, all real names are going to be replaced in the oral and written data sources during the transcription and/or digitalization process. Any other identifying information will be modified, replaced, or deleted to avoid that someone can figure out participants' identity. All digital files (written documents, audio files) will be saved in a password-protected computer, and only researchers working in the project will have access to these documents. All files will be deleted after the analysis is complete at the conclusion of this project.

Research Subject's Consent to Participate in Research:

To voluntarily take part in this study, you must sign on the line below. Your signature below indicates that you have read or had read to you this entire Consent Form, and have had all of your questions answered.

Your Name: ____________________Your Signature: _________________Date:________

Researcher Name: _____________________Signature: ________________Date:________

If you have any questions or concerns regarding your student's rights as a participant in this study, you may contact the Institutional Review Board (IRB) Chairperson at 706.542.3199 or irb@uga.edu.

Please sign both copies, keep one and return one to the researcher.

Appendix G: IRB Documents

UNIVERSITY OF GEORGIA

Tucker Hall, Room 212
310 E. Campus Rd.
Athens, Georgia 30602
TEL 706-542-3199 | FAX 706-542-5638
IRB@uga.edu
http://research.uga.edu/hso/irb/

Human Research Protection Program

EXEMPT DETERMINATION

March 6, 2020

Dear Julie Kittleson:

On 3/6/2020, the Human Subjects Office reviewed the following submission:

Title of Study:	Study of the design process of a science method course by prospective science teacher educators
Investigator:	Julie Kittleson
Co-Investigator:	David Jackson Jose Manuel Pavez
IRB ID:	PROJECT00002008
Funding:	None
Review Category:	Exempt Flex 7

We have determined that the proposed research is Exempt. The research activities may begin 3/6/2020.

Since this study was determined to be exempt, please be aware that not all future modifications will require review by the IRB. For more information please see Appendix C of the Exempt Research Policy (https://research.uga.edu/docs/policies/compliance/hso/IRB-Exempt-Review.pdf). As noted in Section C.2., you can simply notify us of modifications that will not require review via the "Add Public Comment" activity.

A progress report will be requested prior to 3/6/2025. Before or within 30 days of the progress report due date, please submit a progress report or study closure request. Submit a progress report by navigating to the active study and selecting Progress Report. The study may be closed by selecting Create Version and choosing Close Study as the submission purpose.

In conducting this study, you are required to follow the requirements listed in the Investigator Manual (HRP-103).

Sincerely,

William Westbrook, IRB Analyst
Human Subjects Office, University of Georgia